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# FINAL FRONTIER

The Magazine of Space Exploration

April 1988 USA $3.00/CAN $4.00

**EXCLUSIVE:**
A SOVIET COSMONAUT'S ARTISTIC MUSE

ISAAC ASIMOV: IN PRAISE OF NEAR SPACE

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# APRIL

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# LETTER
## from the Publisher

*And but for the sky there are no fences facing.*
*BOB DYLAN*

Welcome to the premiere issue of FINAL FRONTIER the magazine of space exploration. I hope you can feel the electricity that went into these pages. We sure do.

This issue alone started a current between more people than I could have possibly imagined. A cosmonaut/artist, moonwalkers, novelists, visionaries, supporters, not to mention art directors, keyliners, messengers and other deadline-pressed types. And these are just the first sparks of what I'm beginning to realize is a chain reaction.

I think we've tapped an immense international community with a single common belief. Space is back.

Sure, it looked like the quest was abandoned. It floundered, it took wrong turns, it even came crashing down, but it was waiting for us all along.

The Challenger and The Seven may not have challenged the stars, but they've challenged the rest of us. Can we pick ourselves up and brush the stardust out of our eyes?

FINAL FRONTIER believes we can, believes we must. And so we christen the launch of our new magazine with a single mission — to further the exploration of space.

It's no coincidence that our launch anticipates the launch of the new shuttle era. The upcoming lift-off of Discovery is to us symbolic of the renaissance. Things are looking up for space exploration.

We're planning manned expeditions to Mars. Orbiting space stations. Space tourism. International ventures among countries that ordinarily spend their time haggling over currency rates and bullets. Private companies are making huge inroads. And NASA is planning a new program dedicated — believe it or not — to SETI: the search for extraterrestrial intelligence.

And so the dreamers never went away. We may have gone underground for a while. But we never stopped dreaming.

Although we imagine great things for humankind's greatest adventure, we proceed with our eyes open. FINAL FRONTIER will also discuss the downside of looking up. Is space exploration becoming too commercial, too competitive? Is space becoming just another playground for generals?

We'll look at space exploration from every side. Because FINAL FRONTIER is a forum for the imagination — no matter what direction great thinkers may take.

So brace yourself for an incredible journey into the last, vast, uncharted and unfenced world — the final frontier. With any luck, we'll find ourselves, like the song says, " beneath the diamond skies with one hand waving free."

William Rooney
WILLIAM ROONEY
Publisher


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**The Magazine of Space Exploration**

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## THE SPACE STATION: WHAT WILL IT DO FOR US ON EARTH?

For more than three decades mankind has explored the mysteries of the universe from a vantage point in space. Now we're turning space into a practical place to work.

By the mid-1990s NASA's Space Station is scheduled to give science a permanent platform in orbit. A place where researchers can examine our world from a unique perspective and experiment under conditions of extreme temperature and weightlessness.

In zero gravity, compounds can react in ways not possible here on Earth. Scientists can create better medicines, more-durable plastics, and stronger alloys made of metals that resist mixing under gravity's pull. The Space Station also will give astronomers a manned observatory for long-term studies of the universe, while Earth scientists will gain a facility from which to better understand our planet.

There are currently four major work packages in the Space Station's development. Lockheed is a key member of three. These packages are to become the foundation of a permanent presence in orbit that promises dramatic advances in our understanding of space and its usefulness to people on Earth. Drawing on decades of experience in countless areas of space science and technology, Lockheed is helping give mankind an invaluable tool with which to master this new frontier.

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# THE OBSERVATORY

## Spacepeople

*Some thoughts about leaving our home planet.*

▼ ▼ ▼ ▼ ▼

*By Isaac Asimov*

I think that our object should be to get Earthpeople out of the space business. We're not really suited to it. We live an abnormal life, stuck to the *outside* of our spaceship Earth. We are spoiled by a constant gravity, and by an ecology so huge that we are not conscious of the cycling of air, food and water.

The result is that an ordinary spaceship or space station is alien territory to us. The cramped quarters *inside* the hull, the abnormal gravitational pull and the tight cycling of necessities are all so difficult to live with.

Of course, we can manage a flight to the Moon; the round trip is less than a week. And we can stay in space for at least seven or eight months, as long as we're close enough to Earth to remain in touch and to count on rescue in case of emergency.

What about the distant flights, though? Flights to Mars and beyond? We're not really suited to that, and I'm not sure we can make it. What do we do, then?

Here is my suggestion. I would like to see us concentrate on the Earth-Moon system for a while. Let's build space stations in orbit about the Earth, let's build mining stations on the Moon, let's build observatories, laboratories and factories in the space between here and the Moon. Let's even build space settlements in which thousands of human beings can live in Earth-like environments (except that the pseudo-gravity induced by rotating a settlement would produce un-Earthly effects.)

It may take a century of hard work and concentrated effort, but as we approach the year 2100, we should have a smoothly working space-centered society based on the Earth-Moon system. It will get its energy from the Sun, and its materials (except for carbon, hydrogen and nitrogen) from the Moon. The settlements will be exporting food and energy to Earth and will supervise the factories that will take advantage of the peculiar properties of space.

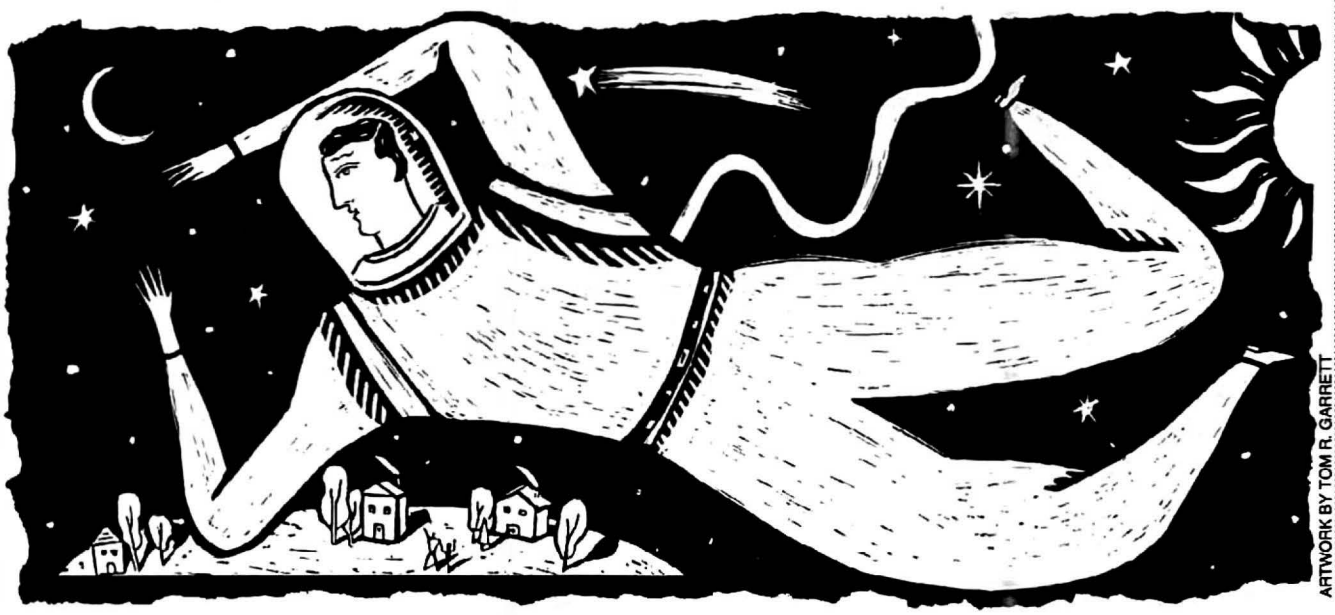
What's more, the space settlers will have an environment suitable for spaceflight. Not only will they be accustomed to space, they will live in what amounts to a large spaceship. They will live on the *inside,* subjected to variable gravity and conscious of the tight cycling of air, food and water.

They can get into a smaller spaceship and go off on long trips. They will be psychologically suited to it, as Earthpeople are not. They will not experience the same radical change of environment in a spaceship that we would.

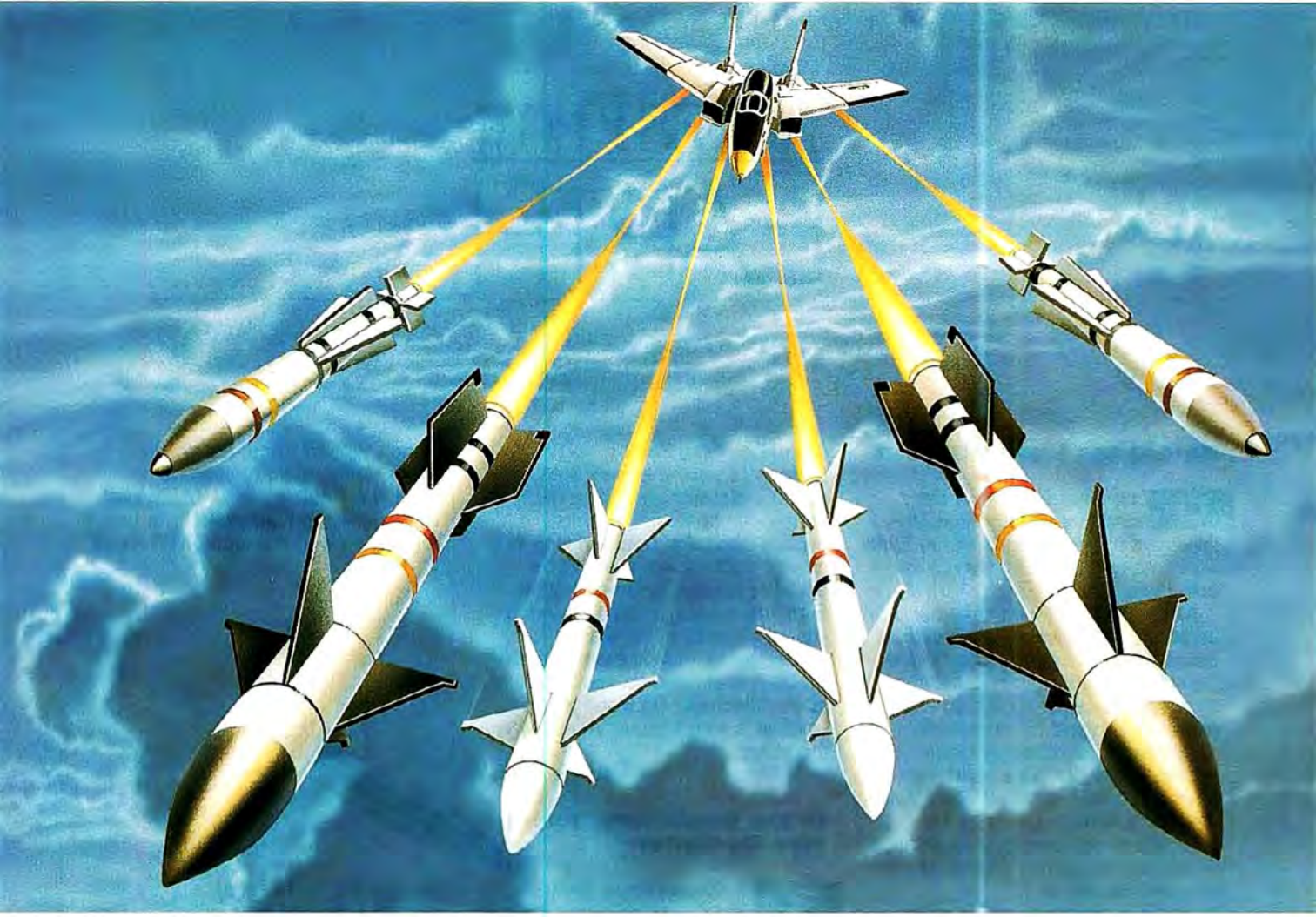
It is the space settlers, then, who will be the new Phoenicians, Vikings, and Polynesians — the great navigators of the future. It will be they who will reach Mars, the asteroids, the various smaller bodies in the vast reaches of the outer Solar System.

Not us. Not the people of Earth with our abnormal way of life that ties us down and makes us prisoners. □

Isaac Asimov



ARTWORK BY TOM R. GARRETT



# IMAGINE ONE JET WITH THE FIREPOWER OF A WWII SQUADRON.

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# NOTES FROM EARTH

## Before the Lights Go Out

One day our Sun will die, and in its death throes the sustenance it provides to life on Earth will come to an end. Those are the cold facts.

Although old Sol isn't scheduled to expire for some seven billion years, Soviet theorist L. M. Shkadov of the Central Aerohydrodynamic Institute in Moscow has sketched out an escape plan for Earth and its inhabitants. "The time of the relatively stable lighting of the Sun as a source of energy is finite," reported Shkadov at last year's 38th congress of the International Astronautical Federation in Brighton, England. "Therefore, to preserve the life of civilization...mankind should worry about a new source of heat and light energy. It might be another star that would replace the Sun."

Shkadov's simple plan is to move the entire Solar System to take up residence in another part of the galaxy. This interstellar commute

would be accomplished by placing an immense, curved "Sun screen" at a point in space where thrust produced by sunlight reflecting from its surface would set our star and its planets in motion.

Based on his calculations, Shkadov said that in 200 million years, a deflection of the Sun by 10-12 parsecs (a parsec equals 3.26 light years) is possible. In a final burst of equations, the Soviet scientist hypothesized that upon arriving at a new galactic locale, it would be possible to execute a hand-off of Earth into a circular orbit around a younger and healthier star.

"Of course, this problem is highly complex and needs a special study," added Shkadov. No word yet on whether a World Transit Authority is in the offing.

*- Leonard David*

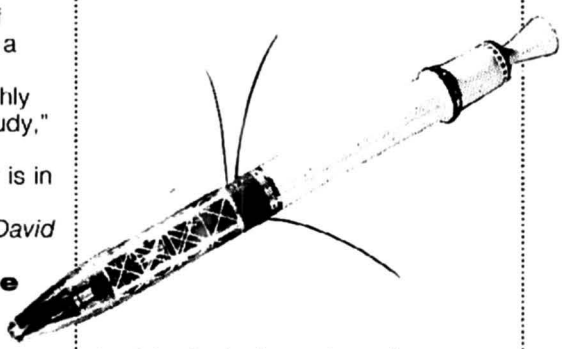
## In the Beginning, There Was Radiation

Thirty years ago, things didn't look so bright for the fledgling U.S. space program. The first American attempt at an orbital launch (after two Soviet successes) in December 1957 had fizzled on national TV as the tiny Vanguard 1 satellite and its rocket exploded on ignition.

With a debacle on its hands, the Eisenhower Administration okayed a crash effort to loft a small satellite using the Army's tried-and-true Redstone booster. The launch team was headed by Wernher von Braun, the spacecraft team by James Van Allen of the University of Iowa. The project was dubbed Explorer, and a launch was set for January 1958.

The 30-pound spacecraft was quickly assembled by several of Van Allen's graduate students, including George Ludwig, who in later years became head of the nation's weather satellite program. Ludwig remembers driving across the Midwest at night from Van Allen's Iowa lab to the Jet Propulsion Laboratory in Pasadena, California with parts for the satellite in the trunk of his car. At that time, few people outside the Army were even aware the secret project was underway.

Explorer 1 would carry a payload of temperature sensors, Geiger counters to measure radiation in space, and a microphone to listen for meteor impacts on the satellite's skin. The launch slipped twice, but on the warm Florida night of January 31, 1958, the Redstone and its payload were fueled and launched. The rocket slipped beyond the arcing horizon of



the Atlantic. In those days, there was no NASA worldwide tracking network, and Van Allen and his team had to wait 90 minutes for the craft to return over the United States to learn if Explorer had made it into orbit.

Shortly after midnight, an agonizing several minutes later than predicted, the first signals from Explorer 1 were received. The United States was in space! Van Allen's name had become a household word by the time co-worker Ernie Ray left a note on his desk later that February, reading: "Space is radioactive!" The Van Allen belts of trapped radiation circling the Earth had been discovered. Both Soviet Sputniks had missed it, and the infant U.S. space program had its first bona fide discovery.

Public excitement and interest in the new frontier grew immeasurably after that. Recalling those days, George Ludwig said, "From then on, the Moon was just a matter of time."

*- Alan Stern*

## Castles in the Sky

It may be a while before there are subdivisions in orbit, but some architects are preparing themselves now for the future business of designing offices and homes in space.

John Spencer, architect and partner in the Los Angeles-based

Design Science firm, has come up with the idea for the International Association of Space Architects (IASA). According to Spencer, about a dozen architects in the world have done design work under contract to NASA or to space agencies in other countries. He estimates there are about 20 more who would like to work on space architectural projects. Add another 50 or so interior designers who'd like to humanize the spaces in space, and Spencer believes IASA will start out with about 100 members.

The goal of the new association, he says, is to communicate with all designers interested in building above-the-sky-scrapers. Associate memberships are even available for non-professionals. The organization would establish quality control standards and professional ethics, and develop education and research programs.

IASA has yet to have its first meeting, but members are actively being sought. According to Guillermo Trotti, associate director of the Sasakawa International Center for Space Architecture at the University of Houston, "This is a different business to get into. It's not like Earth architecture — it's more like craft design. Here at the University of Houston we are graduating architects who have the mentality for space architecture."

ARTWORK BY PAT RAWLINGS

Someday, Spencer says, IASA will have an office in space. In the meantime, there are plans to publish a newsletter as well as a journal of space habitation and design, and Spencer expects the first IASA convention will be held this year. It will be here on Earth.

*Robert Moulton*

## A Venus of a Different Color

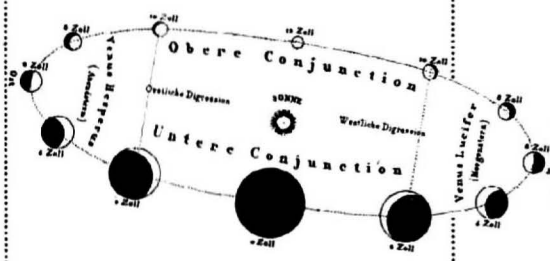
As if Venus weren't strange enough already, our nearest planetary neighbor has been appearing even stranger lately. While recent radar studies are showing the first evidence of Earthlike crustal plates on Venus, James Garvin, a planetary geophysicist at NASA's Goddard Space Flight Center, has been studying the surface of that hellish world from color photos taken by the Soviet Venera landers in 1982.

Garvin and his colleagues have found that the Venusian surface is bathed in a perpetual orange glow. "The clouds contain droplets of sulfuric acid and other carbon, oxygen and sulfur compounds," said Garvin, "and these filter out most of the blue light that we're so used to here on Earth. So, when we applied corrections to the images, we found that the surface is actually a rather gray world much like the Moon." Venera photos previously have been interpreted as showing the rocks to be reddish-brown.

The researchers also are using data taken by a spectrophotometer onboard the landers to study the composition of the planet's surface. "We think we're seeing the effect of ambient high temperatures on Venus cooking the rocks," Garvin said. "If you take an oxidized piece of reddish rock here on Earth and cook it to about 1000 degrees Fahrenheit [a typical day on Venus], that rock would turn black," he says, particularly in a carbon dioxide atmosphere.

"We don't know a lot about the chemistry of the lower atmosphere of Venus, or how its rocks and atmosphere interact," Garvin added. "So people are reevaluating the [Venera] color images. That's the only way we have at present of learning what the ground is made of."

*- Dennis Mammana*

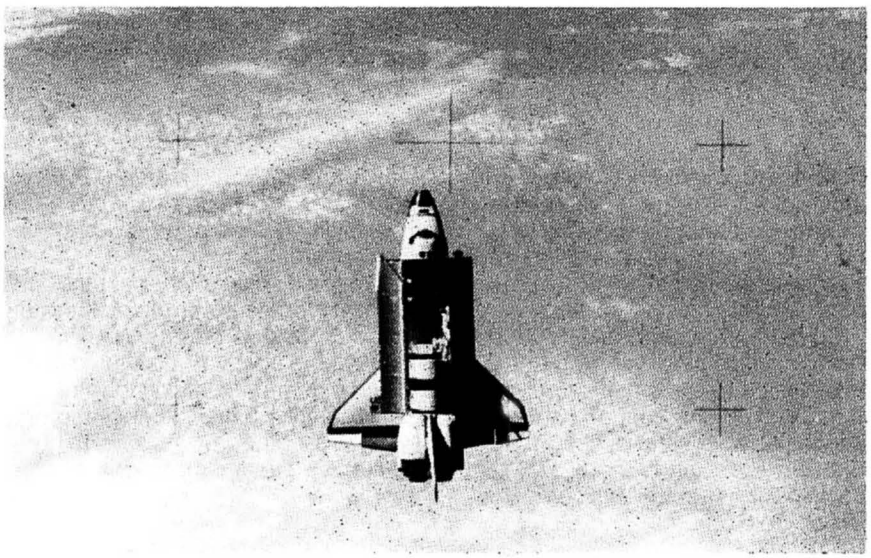



## Prime Time

Down in Florida, which has seen more than a few launches in its time, private launch companies are multiplying like swamp grass. One of the newest, inspired by a mix of patriotism and the desire for profit, is run by a group of ex-NASA engineers.

Bob Davis, head of the recently formed E-Prime Aerospace Corporation, based near Cape Canaveral in Titusville, is worried that the United States might lose out in the satellite launch marketplace to foreign vehicles like the European *Ariane* and the Chinese *Long March* rockets, because domestic launchers aren't competitive. "I'm a red, white and blue taxpaying American," says Davis "and I don't want any foreigners comin' in here and bleeding off all our technology."

However, he adds, concerns about Soviet launch capability are overblown: "We've thrown away better rockets than they're launching now." E-Prime wants to offer customers the full range of launch services, from lofting suborbital experiments to carrying giant



**The shuttle as photographed from SPAS in June 1983.**

communications satellites into orbit. The company is taking a "piece parts" approach to building its rockets. Already it has a "substantial" deposit down with Morton Thiokol, builder of the shuttle's booster rockets, for hardware for a small, Scout-class vehicle capable of lifting hundreds of pounds of payload, according to a Thiokol marketing vice president.

"I can say they're being taken very seriously at Morton Thiokol," said the official. "They're not a Martin Marietta or a McDonnell Douglas, but they can offer a very reliable launch service."

E-Prime will launch its small rocket as soon as the Air Force gives the company permission to use one of its ranges at Cape Canaveral. The Air Force says that permission is "imminent." When it's given, the company will loft several experiments to explore the behavior of materials in microgravity. Davis hopes E-Prime's next job will be a promotional flight from Australia's new Queensland launch site, but there are still many regulatory issues to be worked out.

Another hurdle facing the company is a lawsuit by a major shareholder, who alleges that the company abrogated a $10 million deal, and still owes an investor a $500,000 installment on the funding — half the company's assets. Other investors aren't deterred by the allegations, saying the potential payoff outweighs the risk.

Meanwhile, the disgruntled shareholder took the deal E-Prime refused and transferred it to his own new company, Aerospace Systems International, in Titusville. President Raymond Cerrato says he will use the capital for "what else? We're in the rocket business. We plan to corner whatever market is available."

*- Melinda Gipson*

## Das SPAS

Its earthly origins were in sailing masts and scuba tanks. Now, five years after it first reached orbit, Germany's SPAS "space platform" is still a low-cost solution looking for problems.

Conceived in the 1970s as a simple, multi-user spacecraft, SPAS can fly either as a fixed platform resting in the shuttle's cargo bay, or as a free-flying satellite deployed and retrieved by the shuttle's robot arm. Made of lightweight carbon tubing joined by titanium modules, this orbiting "raft" can be configured like an erector set, complete with its own thrusters, computers and communications antenna.

SPAS' builder, Messerschmitt-Boelkow-Blohm, cut development costs by letting creative engineers use off-the-shelf parts. The platform's carbon tubes were adapted from wind-surfer masts. Containers for pressurized propellant were modified scuba tanks costing less than $1000 each, rather than the estimated $250,000 an aerospace company would have charged to design them from scratch.

SPAS-01 had its first spaceflight on shuttle mission STS-7 in June 1983. Seven German and three European experiments were onboard, along with a 70 mm NASA camera that took the first pictures of a shuttle orbiter against the backdrop of space. A second SPAS flight followed on STS-10 in February 1984, but since then, the space-raft has yet to return to orbit.

Some SPAS applications have failed to get off the ground, including an aborted venture to take Earth photographs for profit, while others still plan to fly. An American SDI experiment will make use of SPAS in orbit in 1989, and ASTRO-SPAS, a joint U.S.-German project, will place astronomical telescopes on a free-flying platform in 1990. And DOM (a German acronym for German Orbital Laboratory) will offer SPAS as an affordable platform for commercial microgravity experiments.

According to Konrad Moritz, SPAS program head at Messerschmitt-Boelkow-Blohm, the company would like to market SPAS as a low-cost commercial platform for a variety of users. Small customers could have to wait, however. SPAS, considered a leading candidate for the NASA/international space station's "co-orbiting" platform, may soon have high-paying government customers knocking at its door.

*- Helmut Muller*

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Amateur astronomers who've outgrown their backyard reflectors will soon have a chance to use the most powerful telescope ever built for stargazing. Proposals for amateur observations using NASA's Hubble Space Telescope are being accepted through June. The total observing time alloted to amateurs is tiny — only two to three hours a year — but all serious proposals will be considered. Scheduled for launch in 1989, Hubble will see objects up to 50 times fainter than the best ground telescopes from its vantage point above the atmosphere. For information on how to submit proposals, write the American

Association of Variable Star Observers, 25 Birch Street, Cambridge, Massachusetts, 02138.

▼ ▼ ▼

The National Council on Radiation Protection and Management has recommended lower acceptable dosage limits for astronauts exposed to harmful radiation in space. In a study commissioned by NASA, the Council considered such factors as the increasing number of people working in space in the future, as well as recent studies showing a greater cancer risk (per unit dose) among A-bomb survivors. The council recommends that annual exposure limits (in rem units, a measure of dosage and radiation quality) be reduced from 75 to 50 rem for "deep" body organs, and that career limits for space workers be reduced from 400 down to a range of 100-400 rem, depending on sex and age at the start of the career. According to a NASA report, "the doses from galactic cosmic radiation in polar orbits and in free space are poorly known."

▼ ▼ ▼

Among the proposals placed on — or at least near — the negotiating table during last December's summit meeting in Washington was a U.S.-Soviet mission to Mars. During a reception at the Soviet embassy for assorted American intellectuals and celebrities on December 8, Secretary General Mikhail Gorbachev was asked what could be done to further cooperation between the two nations. His immediate answer: a joint expedition to the Red Planet. So far, no U.S. official has taken the bait. Meanwhile, the Soviets plan to launch their Fobos robotic spacecraft to explore Mars and its two moons, Phobos and Deimos, in July.

▼ ▼ ▼

After more than two years of competition among a dozen aerospace companies, NASA has awarded contracts for final design and construction of its proposed space station, set to be assembled in Earth orbit (pending future budget cuts) in the 1990s. The two biggest contracts went to the McDonnell Douglas Astronautics Company ($1.9 billion for building the station's structural framework) and the Boeing Aerospace Company ($750 million for two pressurized "modules" containing laboratory facilities and crew quarters, plus attendant life support systems).

▼ ▼ ▼

It may not be obvious on your map of the Solar System, but one way to reach Jupiter is to visit Venus first. At least that's the route selected for NASA's Galileo spacecraft, which was stranded without an engine powerful enough to reach Jupiter directly when the agency canceled its Centaur upper stage rocket program in 1986. Now NASA plans, in 1989, to launch Galileo toward rather than away from the Sun. The spacecraft will pick up enough energy when it flies past Venus in 1990 (a technique called "gravity assist") to hurl it back toward Earth. Its orbit will be "pumped" further by two gravity assists from Earth (in December 1990 and December 1992), after which the rambling robot will finally have enough energy to make it to the outer Solar System. Galileo arrives at Jupiter in December 1995 to begin two years of close investigation of the giant planet and its moons.

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How long would it take to turn Mars into Earth? Christopher McKay of NASA's Ames Research Center has considered the future of "terraforming," or engineering another planet's environment to be more hospitable to humans. Step 1 — warming the Martian atmosphere (by reflecting sunlight from giant mirrors, perhaps, or by introducing "greenhouse" gases that trap solar energy) — would take a mere 200 years, writes McKay in a recent issue of the Planetary Society's Planetary Report. Step 2 — stocking the atmosphere with breathable oxygen and nitrogen, courtesy of imported micro-organisms, plants and animals — takes a little longer: up to 100,000 years, by McKay's figuring.

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Score one for the commercial space launch business. The U.S. government in October selected General Dynamics Space Systems Division, builders of the Atlas Centaur rocket, to launch three GOES weather satellites into orbit from 1990 to 1992. It was the first purchase under a new government policy to encourage the growth of a private launch industry in the United States.

▼ ▼ ▼

The Air Force Astronautics Laboratory at Edwards Air Force Base in California is studying designs for an advanced solar-powered rocket that could ferry satellites from low to high orbits above the Earth. Using solar energy to heat liquid hydrogen, the rocket could achieve high efficiencies. Such an engine would be able to transfer a 17-ton cargo from a low (typically 200-mile) orbit to an altitude of 22,000 miles in two to three weeks. According to an article in Aviation Week and Space Technology, the laboratory plans to demonstrate the engines in space in the mid-1990s.

## Galactic Events

**April 5-7,** Houston, Texas. Lunar Bases and Space Activities of the 21st Century, a scholarly symposium on technologies and strategies for lunar settlement. Co-sponsored by NASA. Information: (713) 483-6605.

**April 26-29,** Cocoa Beach, Florida. Twenty-fifth Space Congress with technical papers on space stations, Mars missions, commercial space enterprises, future launch vehicles and more. Sponsored by the Canaveral Council of Technical Societies. Information: (305) 867-3494.

**May 27-30,** Denver, Colorado. 1988 International Space Development Conference, covering a wide range of subjects of interest to the space aficionado, from space culture to starting your own space-related business. Hosted by the National Space Society. Information: (303) 692-6788.

# THE PRIVATE VECTOR

## Betting on Space

*So far, only a few companies have taken the big gamble.*

▼ ▼ ▼ ▼ ▼

*By Melinda Gipson*

In the dim dawns since Black Monday, Wall Street has been redefining the nature of risk. After the market crash, investors fled even well-established aerospace stocks for the security of so-called blue chip companies. So how can entrepreneurs hoping to stake their futures in space even hope to raise cash for this riskiest of all marketplaces?

They may as well forget about most major financial institutions. Space is too big, too far away and too expensive for the average Wall Street executive to fathom. This pin-striped, portfolio-laden, bull rider is more interested in next year's projected earnings than in whether a serum for a rare blood disease can be manufactured in orbit in the next decade.

Venture capitalists look for profitability in companies within three to five years — five being the outside. Space engineers are used to taking that long just to design and build structures that will provide innovative services in space.

In identifying who is still willing to bet money that space will pay off, it's important to remember that there's not an investor in America who didn't see what was presumably the safest space vehicle ever built disintegrate into thousands of pieces in the blue sky over Cape Canaveral.

In the ensuing 27 months since the *Challenger* disaster, several companies whose businesses were based on servicing NASA's so-called "space truck" and the satellite cargo it carried have gone bust.

But one such casualty recently sold out to another venture with the right combination of big backers and service offerings required for success in the space marketplace. The buyer was Space Industries Inc., a Houston-based firm that hopes to build and launch orbital factories called Industrial Space Facilities by the early 1990s. Among the company's guiding spirits are president Maxime Faget, whose space experience dates back to designing the Mercury capsule in the 1950s, and vice president Joseph Allen, a former astronaut whose second shuttle mission in 1984 plucked two satellites from orbit and brought them back to Earth.

Space Industries will be staking more than half a billion dollars that space will pay off in spades. With its partner Wespace, a Westinghouse Electric subsidiary, and backers like Boeing, another major aerospace firm, the company plans to build two Industrial Space Facilities and launch them on the shuttle. Major pharmaceutical labs or other researchers interested in testing the properties of materials in the vacuum and reduced gravity of space would then pay Space Industries to use its facilities.

If they do, that means Space Industries will need a place near NASA's shuttle launch site where it can install experiments and prepare the space factories before they are launched. So, last September the company bought a "used" payload processing facility in Florida.

The former owner, Astrotech Space Operations, couldn't even pay its rent on the facility, which was designed to ready commercial satellites for shuttle launches. Space Industries, bolstered with cash from Wespace and Boeing, hopes that business is humming by 1992 — the year it hopes to place its first facility in orbit.

Therein lies another wild card. What's to keep NASA, which has had five major launch policy shifts in as many years, from reneging on its promise to launch Space Industries' first facility on time? The answer may lie in NASA's plans to make use of the facility itself.

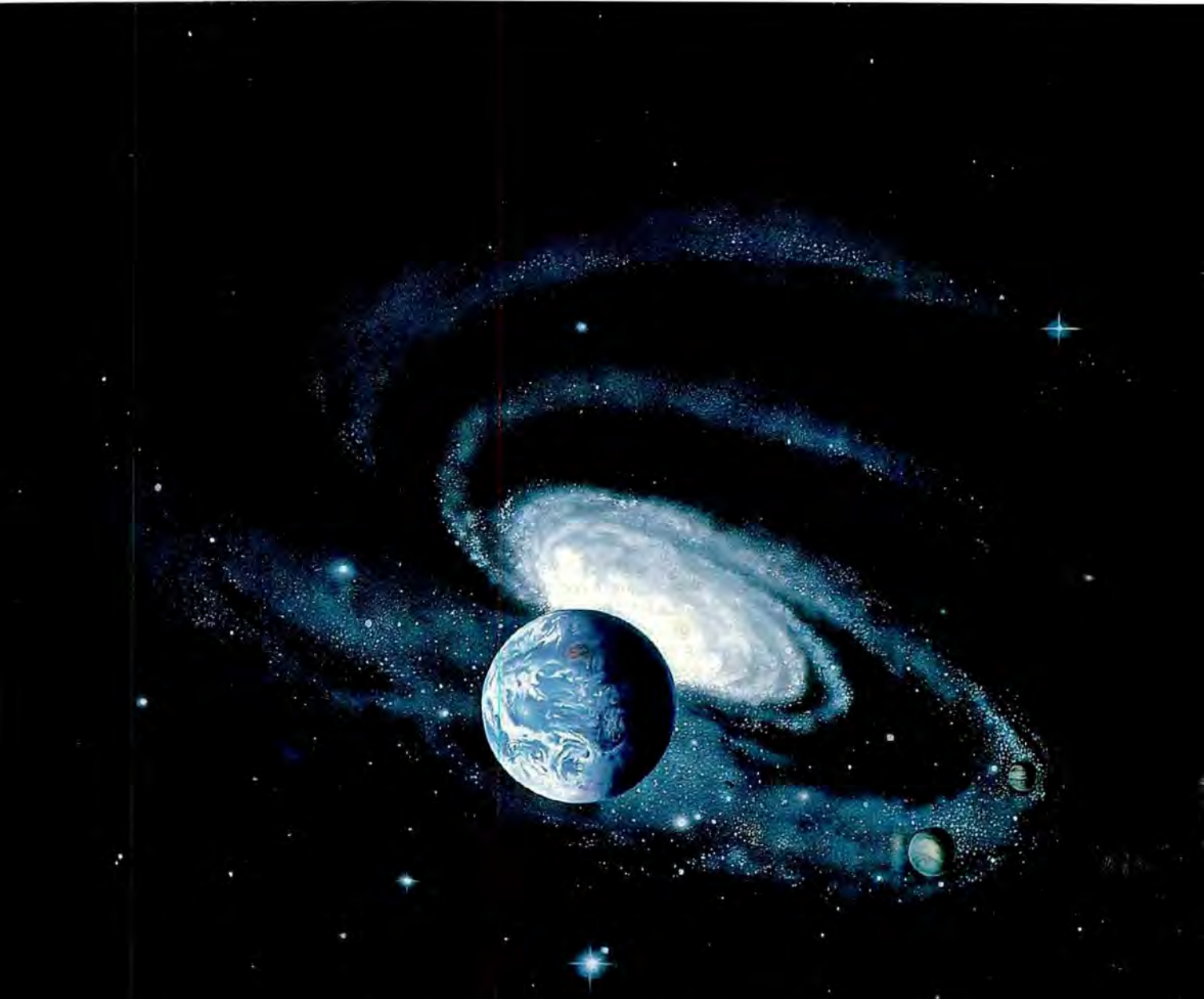
Wisconsin Senator and long-time NASA critic William Proxmire's fascination for the privately operated Industrial Space Facility nearly cost NASA its whole space station program last year. Proxmire — who was outnumbered by other Senate space supporters — would have delayed the station indefinitely and sent up a few smaller space factories to see whether the enterprise really is worth the billions of tax dollars being spent on it. As it is, the space agency is now exploring the idea of renting space on the ISF as a complement to space station capabilities.

Another start-up company based in Seattle, Spacehab Inc., hopes to market the use of a shuttle mid-deck extension module — a kind of add-on room that would sit in the vehicle's open cargo bay — which later could be plugged into the station and returned for servicing aboard the shuttle. Here again, the company's first customer may be the government, in this case the Defense Department. DOD's space budget is getting so big so fast that companies with any promise of doing things cheaper in space may find start-up capital in the Pentagon.

But to succeed ultimately, these firms must have more than government business. They need to establish impressive enough cash flows to attract the bull riders, at least until someone proves that there really is money to be made in space.

The entrepreneurs' greatest allies in this endeavor may be the established aerospace firms. Boeing, the company investing in Space Industries, last summer founded a new subsidiary, Commercial Space Development Co. to foster commercial, space-based ventures. Although the development company was capitalized at only $20,000 when incorporated, the full weight of Boeing's corporate resources are behind it.

In time, other aerospace companies may also pick up the baton and realize that successful competition with others of their ilk depends in part on the ability to recognize and fund a good thing when they see it. □



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# SPACEFARERS

## Own A Piece Of The Rocket

*The W.S.F. takes do-it-yourself to new heights.*

▼ ▼ ▼ ▼ ▼

*By Maura Mackowski*

"We provide anyone who wishes to become directly involved in space research the opportunity to do so."

Rob Staehle and the World Space Foundation make that a promise. Send them $15 and they'll build you $15 worth of flyable hardware or fund $15 of space-related research. If you're the hands-on type, WSF welcomes volunteers with skills that range from engineering to fund-raising.

The Foundation took off in 1979 when some disgruntled Jet Propulsion Laboratory (JPL) employees decided they had had it up to their collective eyeballs with what they saw as a lack of funding, commitment and leadership on the part of NASA, Congress and the general public. They put their money on the table, their faith in the free enterprise system and their noses to the CRT, and chose, in essence, to operate their own space program.

Today WSF receives contributions from sponsors in 20 countries. A work force of some 60 volunteers in and around Pasadena, California are augmented by a small paid administrative staff. "We aren't organized into local chapters," Staehle said. "We believe that would detract from our goals. We participate in no political activities, either. *Here's* what we do,' we say, 'judge us by that.'"

The group funnels its money directly into a few carefully selected research projects. "We pick those with a relatively modest level of activity, within our means," Staehle said. Tops on the spending list right now is the solar sail project, which aims to build a space vehicle propelled by the pressure of sunlight rather than by fuel. Designed entirely by WSF members, the solar sail is waiting for funds to begin actual construction, with the first tests in Earth orbit expected by 1990.

Among the applications for solar sails would be sending a spacecraft to rendezvous with an asteroid, or carrying cargo for a manned interplanetary mission. "You send a fleet of solar-sail powered vehicles ahead with supplies, a year or so before the manned vehicle," explains Emerson La Bombard, manager of the WSF solar sail project. "Because solar sail propulsion is slower, the fleet and the manned ship would get there at the same time."

Staehle admits that there are no immediate commercial opportunities for the solar sail, but says that "in the long term, say 20 or 30 years, our investment now will be seen as a catalyst. It's pure research."

Number Two on the list of projects is an asteroid research program headed by Dr. Eleanor Helin of JPL, whom the WSF supports with funds, equipment and volunteer staff. Staehle hopes that Helin's work to locate near-Earth asteroids will identify suitable targets for the first applied flight of a solar sail. Other members are working on designs for a lunar polar base, an industrial space station and a new passenger spaceplane.

When she first joined the WSF, Kristin Lattu, a JPL engineer, had assumed that the members would be other space scientists and engineers. But, she said, "We're getting mail from places like Nebraska and North Dakota, rural places with no connection to the aerospace industry. They don't always tell us why they're sending the money. Some of the money even comes from countries that have their own space programs."

Likewise, WSF volunteers are not always the hotshot young engineers one might expect. La Bombard was a McDonnell-Douglas executive who logged 45 years in the aircraft business, including time as project manager for the DC-10, before retiring as Director of Productivity.

"I'd been an airplane man all my life," La Bombard said, "but I didn't know anything about space. I saw a paragraph in an AIAA (American Institute of Aeronautics and Astronautics) publication that said they (WSF) needed a project manager, so I called them. I knew I could certainly wave my arms and talk about cost overruns. Now I give speeches and sound terribly smart about space," he laughed.

"What made me want to stay with the World Space Foundation was how surprisingly low-tech this type of project is," he added. "Nothing is really sophisticated. It's just nuts, bolts, radios — nothing that everyone in the world hasn't done before. The concept is exotic, but the only real component that is exotic is the sail itself, which is made of plastic. The really high-tech thing will be someday building it in orbit."

Corporations also have been supportive of the foundation, Lattu said. Hughes Aircraft, for example, donated a rocket motor for boosting a satellite to a higher orbit. Some of the monies received are outright donations, others come from subscriptions to the group's three publications. More cash is generated by sales of "I WANT TO GO" space shuttle t-shirts, mugs and other assorted paraphernalia. La Bombard sounded half-serious when he joked about selling advertising space on the baseball diamond-sized solar sail.

The Foundation is also interested in recruiting new talent. The group is definitely not wanting for engineering experts (or "techno-eggheads," as another WSF founder, Ed Nelson, calls them) but could surely find a spot for someone with a gift for marketing or fundraising.

"If we could find the right one million people and get them to give $10 each we could reach our goals," said Nelson. "We haven't found that secret yet, but I'm sure we will. The longevity of the group is a key to its credibility." □

*For more information, write to the World Space Foundation, P.O. Box Y, South Pasadena, CA 91030-1000.*

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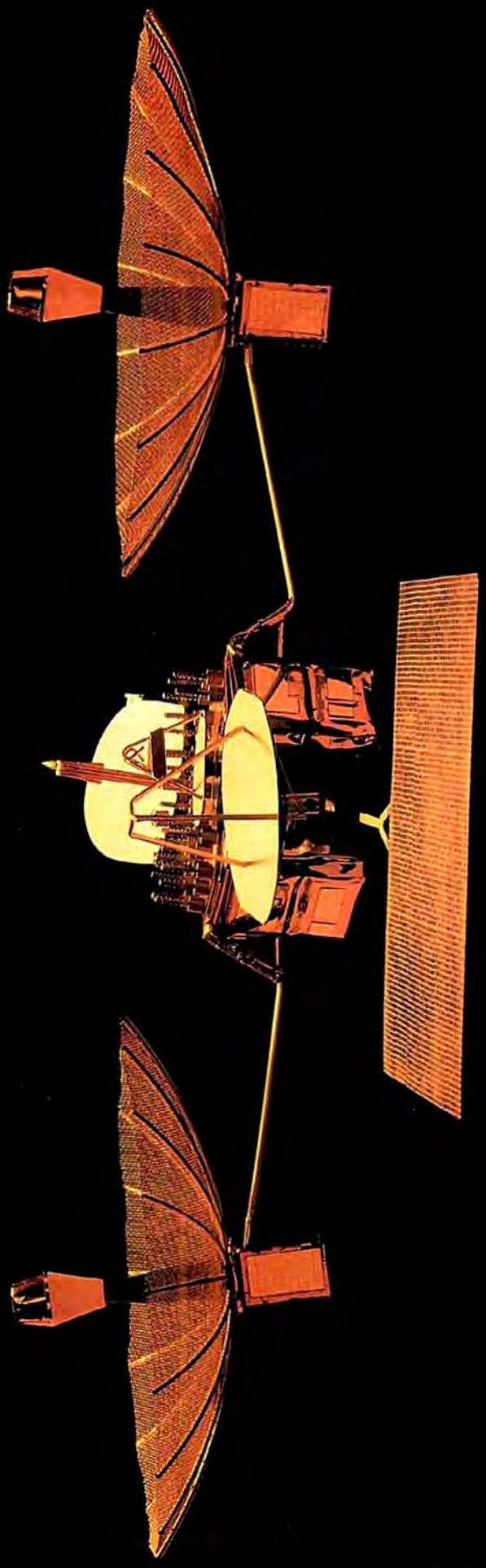

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# REVIEWS

*Before Lift-off: The Making of a Space Shuttle Crew*
By Henry S.F. Cooper, Jr.
The Johns Hopkins University Press
270 pages. $18.50

*By Thomas O'Toole*

▼ ▼ ▼ ▼ ▼

If there is a theme to Henry Cooper's new book about how five American astronauts trained in 1984 for the 13th flight of the space shuttle, it is that the words and music for impending disaster were being written less than two years before the *Challenger* disaster of 1986.

The handwriting was on the wall for everybody to see, from the rapidly rising flight rate and tendency to think of shuttle launches as routine, to the overcrowded training schedule, flight postponements and inevitable stress brought on by late changes to crews and payloads.

Cooper also documents the growing arrogance of America's space engineers. He tells a chilling tale of how the book's principal subjects, the crew of shuttle mission 41-G, came to hear that they would perform an experiment in space using hydrazine, a fuel so dangerous it can explode at 230 degrees (a temperature reached easily on the sunny side of a spacecraft), and so toxic that if the astronauts got any on their spacesuits the fumes alone might kill them when they took off their helmets. Cooper recreates a meeting in Houston where an engineer named Benson was briefing the crew on how they would be the guinea pigs for testing a new technique that could let the Air Force refuel its satellites in orbit and save millions of dollars for the Pentagon. The experiment involved the transfer of hydrazine from one fuel tank to another.

The commander of 41-G was Navy Captain Robert L. Crippen, at the time a veteran of three shuttle flights and the most accomplished astronaut in the corps. Crippen frowned and pursed his lips, Cooper tells us, then asked Benson: "What do we gain by using hydrazine instead of water for a demonstration?" Benson: "We would be demonstrating safe operating procedures, and we couldn't do that with water." Crippen let out a deep breath and looked incredulous. Benson went on: "We truly believe that all the obstacles have been overcome. If we use water now, we would lose the respect of all the potential users. And using water would hurt the morale of the people who've been working on this job." Said Crippen, to general laughter: "Yeah, but it sure would improve mine."

The astronaut who would be handling the hydrazine on 41-G, Navy Lieutenant Commander David C. Leestma, is a man "who never accepted things at face value," according to Cooper. It seems that Leestma wanted to inspect the hydrazine-handling tools he'd use in orbit before they were shipped from the Johnson Space Center in Houston to the Kennedy Space Center in Florida. Not at all anxious to please Leestma, the engineers in charge scheduled his inspection for daybreak just before the tools were to board an airplane.

Leestma discovered that one of the tools didn't fit another tool the way it had to. He couldn't believe it. "And here they were about to bag it and put it on the spacecraft!" he said later. "When I got on the EVA (NASA word for spacewalk), I'd have found out it didn't work."

Loaded with behind-the-scenes stories like these, *Before Lift-off* is a good book, even excellent at times. Cooper, who writes about space for *The New Yorker*, knows the NASA program, he looks and listens well, he knows what makes astronauts tick and he brings life to the machinery they fly. Sample: The space shuttle "looks and flies like an overweight penguin dropped from a tall building."

As good a writer as Cooper is, he can be irritating, with an unnerving habit of inserting himself into his tale. If you try counting how often he says, "Sally Ride once told me," you quickly run out of patience. He tells his story in diary style, which sometimes doesn't work. But these are minor faults. This inside look at astronaut training is a valuable contribution to the nation's space library. □

*Thomas O'Toole covered the space program for* The Washington Post *for 20 years, and is a past winner of the National Space Club Press Award.*

**In his world, George Bender *is* the center of the universe.**

# THE COUNTDOWN BEGINS

*After two years, NASA prepares for its most important launch ever.*

*BY TONY REICHHARDT*

Imagine that fate had been kinder on that morning in January 1986 — that the weather had been milder or the voice of caution more persistent. Imagine that everything had gone according to plan.

*Challenger*, one in a fleet of four busy orbiters, would be recently returned from its second mission in eight weeks. The shuttle would have flown more than 30 times since mission 51-L, 17 in the past year alone. Right now dozens of astronauts would be in training, virtually around the clock, for future shuttle flights.

The Hubble Space Telescope, the most important astronomical tool in four centuries, would be long past its first anniversary in Earth orbit, with a book full of discoveries already to its credit. The *Galileo* spacecraft launched from the shuttle in 1986 would be just a few months away from dropping a probe into Jupiter's swirling clouds, having already taken the first close-up photos of an asteroid on its outbound cruise more than a year ago. Today another spacecraft called *Magellan* would be on the pad ready for an April shuttle launch toward Venus.

All of these people would have flown in space during the past two years: guest astronauts from Britain, India and Indonesia; Air Force Under Secretary Edward C. Aldridge (on the first shuttle launch from California in July 1986); and the first "Journalist in Space," maybe Walter Cronkite, who was one of 40 finalists with a chance to follow Christa McAuliffe as the second private citizen onboard the shuttle. Cronkite's historic broadcast from space would now be old news, file footage dating back to October 1986.

As it is, though, none of these things happened. Some may never, while others are on indefinite hold. As it is, the Florida skies *were* cold and windy that January morning. The O-Ring didn't seal, as a few had feared, and seven people lost their lives.

Now, more than two years later and still counting, the American space program is waking up slowly from the worst nightmare in its 30-year history, as NASA engineers, scientists and astronauts prepare for the first launch of a second, less innocent shuttle era. The nation — indeed, the whole world — will be watching.

Among the spectators will be an

ARTWORK: PAUL HUDSON FOR ORBITAL SCIENCES CORPORATION.

estimated 3,500 news reporters expected to apply for passes to view the launch from the Kennedy Space Center press area, four miles from pad 39-B. "Every single one that calls in says they want to get their request in early, because they think it's going to be a madhouse," says Diana Boles, logistics coordinator for the press site.

A trusting relationship with the media is one of the many stars in NASA's universe that has fallen as a result of *Challenger*. In the dark weeks following the accident, reporters roamed the government-drab halls of the space agency's headquarters in Washington, microphones at the ready, hoping for statements of dejection from members of the losing team. Signs went up in offices at the Johnson Space Center in Houston and at other NASA centers saying, in effect: "Don't talk to the press."

For NASA veterans, that time was — and still is — painful. Richard Truly, a former astronaut who now heads the shuttle recovery program as chief of the agency's office of space flight, told a radio interviewer last November, "I think the greatest frustration has been to have these great people and this magnificent and successful program be criticized. On the other hand, I think we deserved some of that criticism, so my approach has simply been to try to build a team that will win our credibility back."

Truly is as close to the shuttle program as anyone at NASA. He piloted the prototype orbiter *Enterprise* through Approach and Landing Tests in 1977, years before the stubby spaceplane went into orbit, at a time when no one was certain it could fly, let alone make it off the launch pad. Then, he and Joe Engle took the still fledgling vehicle into space on its second test flight in 1981. Truly's STS-8 flight in 1983 was his last before retiring that year to head the U.S. Navy Space Command. Now he's back at NASA, trying to prove, as he did over the California desert a decade ago, that the shuttle system is fundamentally sound.

The rebuilding began even before a presidential commission concluded its official investigation in June 1986, but their report marked an end to one phase of the recovery — the search for a physical cause for the accident. Experts inside and outside NASA agreed that cold temperatures on the day of launch and other factors had caused one of *Challenger's* twin booster rockets to leak hot gases from a seam in its side, which had then burned through the giant external tank's thin skin and ignited its fuel.

By August, NASA and its contractor, Morton Thiokol, had designed new, tighter joints between segments of the giant boosters. The segments are manufactured at the Thiokol plant in Utah and shipped to Kennedy, where they are assembled, four for each booster, into a vertical stack. The new design tightens the joints between segments by adding a steel-lipped capture device, improving the insulation that keeps hot gases in, and adding a third "O-Ring" seal. It was these rubber-like seals that failed on *Challenger*, when low temperatures caused them to lose their resiliency. Heaters also have been added to the joints to protect against the cold.

Since then, most of the recovery effort has been devoted to testing this hardware and other elements of the new design, using small-scale test articles, segments in "joint environment simulators," and fully assembled boosters. By the time all the tests are finished, according to H. Guyford Stever, chairman of the National Research Council panel overseeing the redesign, "the joints and insulation of the shuttle [booster] will be better understood than those of any other large solid rocket motor."

The recovery program passed an important milestone last August 30, with the first full-duration firing of a rocket motor including the new joint design. After being postponed for more than a month, the DM-8 (for Development Motor 8) firing at the Thiokol test range in Utah went off without a hitch. With 520 instruments recording its vital signs, the booster shot out a 500-foot plume of fire for just over two minutes. It was the first bright light in months for an agency that had suffered a seemingly endless string of failures.

Among the 10,000 spectators who gathered that Sunday in Utah to watch the test was the crew for the shuttle's next flight, STS-26. (Mercifully, NASA is back to using a simple numbering sequence for its launches, beginning with this 26th flight of the Space Transportation System.)On its first post-*Challenger* mission, the shuttle will carry five astronauts, all of whom have been in space before. The last time NASA flew an all-veteran crew — perhaps a measure of this flight's symbolic importance — was on Apollo 11, the first landing on the Moon.

The commander for *Discovery's* four-day mission will be Navy Captain Frederick H. (Rick) Hauck, who flew with Sally Ride on her history-making STS-7 journey in 1983 and who commanded the 51-A mission of *Discovery* a year later. In the pilot's seat next to Hauck will be Air Force Lt. Colonel Richard Covey, who also

**Out of the fireball (left) dropped the torn fragments of *Challenger*, which were buried quietly in abandoned missile silos at Cape Canaveral (below) a year later. On the second anniversary of the accident, NASA was still struggling to put the past behind it.**


has flown *Discovery* before, on mission 51-I in 1985. The three mission specialists for STS-26 are Marine Major David Hilmers and two scientist/astronauts: George (Pinky) Nelson, a former astronomer, and astrophysicist Mike Lounge, who was Covey's crewmate on *Discovery* in 1985.

Before he and his crew began intensive training for the STS-26 flight in February of last year, Hauck had been assigned to NASA headquarters in Washington as Deputy Director for External Relations — essentially the agency's head PR man. Hauck was one of several senior astronauts assigned to management positions throughout NASA after the accident. This was partly a response to a specific recommendation by the *Challenger* commission, partly a way to keep non-training astronauts busy, and partly an exercise in confidence building. Having a high-profile figure like Sally Ride head a task force to map out future goals for the agency (as she did before leaving the astronaut corps last summer) has helped the agency overcome the "flawed" image of pre-*Challenger* management.

Of all the astronaut/managers, Truly has carried the heaviest load. Besides the troublesome rocket boosters, he has had other shuttle systems to fix — the main engines and brakes both have required modification during the down time. "We have not made a lot of changes," says Truly, "but the ones we have made are the most important ones."

One fix that may be of more psychological than practical value is the addition of a crew escape system. In the event that the astronauts had to bail out during what is called "stable gliding flight," the orbiter's side hatch would be blown with explosive bolts, and a "tractor" rocket would eject the prone astronauts out the hatchway to parachute into the ocean. But, as Hauck admitted in a NASA video conference in November, the new system will only be of value in a "very small set of potential accidents."

The escape system is not even considered critical for the first flight. The simple truth, says Hauck, is that "there is no escape system we could implement in the space shuttle right now that could have prevented the deaths of our friends aboard *Challenger*."

Shortly after the accident commission released its report, NASA confidently set its sights on February 1988 as the date of the STS-26 launch. But when engineers added two more pre-launch tests to an already crowded schedule — a "wet countdown" with the shuttle fuel tank filled and a "flight readiness firing" of *Discovery's* main engines on the pad — that date slipped.

The slips, and the frustrations, have continued. Last October a date of June 2 was announced. Even before that plan was scrubbed in December due to a new and unexpected booster problem, NASA administrator James Fletcher could only say there

**The crew of the next shuttle mission: (L. to R.) David Hilmers, Richard Covey, George Nelson, Rick Hauck and Mike Lounge.**

was a "fighting chance" of keeping the appointment.

All along, agency officials have admitted that the recovery schedule is "tight" and "success-oriented," a euphemistic way of saying there is no room for mistakes. In November, Truly's response to the "when?" question was that "it doesn't really matter whether we fly on June 2 or June 15 or July 15. What really matters is that we get this system flying again as quickly as we can." By year's end, even a July launch was unlikely. Hauck, for one, doesn't mind using the word "pressure" to describe the recovery program, which, from the beginning, has walked an uncomfortable line between haste and caution. "Some pressure," he says, "is part of the game."

Perhaps the biggest headache for Truly's office in the past two years has not been related to hardware, but to working out a new launch "manifest" of scheduled missions. After months of juggling priorities for various NASA spacecraft, military payloads and other grounded satellites, a revised manifest was released last October.

The first launch of the new shuttle era will pick up where the last one left off. Onboard *Discovery* will be a single primary payload, a Tracking and Data Relay Satellite (TDRS) similar to the one lost on *Challenger*. Eleven "secondary" cargos — smaller experiments stowed inside the shuttle cabin — also will be onboard. Five of these will be microgravity investigations of physical materials, some with possible commercial applications in space.

The other experiments will be in life sciences, communications and atmospheric sciences. These include studies of blood viscosity in low gravity and an experiment to demonstrate a new method of using infrared light as a medium for shuttle crew communications. Two student investigations, both in zero-g crystal growth, will also be included to duplicate experiments that were lost on *Challenger*.

The TDRS system has suffered problems of its own. NASA's intent since the earliest days of the shuttle has been to place a trio of relay satellites neatly spaced in high orbits around the globe, that will allow shuttles and other low-orbiting satellites to be in constant communication with the ground. The first TDRS reached orbit in 1983. Five years later, a second has yet to be launched. Because data-intensive missions like the Space Telescope and Spacelab need a working TDRS system to get their full science return, placing the other two satellites in orbit is a high priority, and the first and fourth shuttle missions will be dedicated to TDRS.

Sandwiched between these flights are two secret military missions. Then, with STS-30, comes the shuttle's first planetary launch ever — the *Magellan* radar-mapping mission to Venus. Science has been the hardest hit of all the shuttle's major constituencies, and to make amends, NASA has tried to move science missions to the top of the new schedule.

Beginning with *Magellan*, four of the next five flights will carry some of the most spectacular projects in NASA's history: the Hubble Space Telescope, a permanent observatory orbiting above the atmosphere, which will give astronomers their first good, unfiltered look out into the universe; an astrophysics Spacelab mission called Astro-1; and (after the STS-33 military mission) the long-awaited launch of *Galileo* toward Jupiter.

But planetary missions also bear

ALL PHOTOS: NASA

**When flights resume, the Magellan Venus radar mapper will be a high priority cargo — the shuttle's first launch of a spacecraft to another planet.**

the greatest risk if the shuttle schedule continues to slip. If a spacecraft bound for another planet misses its launch "window," it can be more than a year before the planetary targets align themselves properly again. *Magellan* may already have to be moved up in the launch order as a result of December's announced delay. So planetary scientists, by now only too used to shuttle-related disappointments, will continue to hold their breath.

A total of five flights are scheduled in the first year after flights resume, with nine the following year. The shuttle will probably never reach the launch frequency expected before Challenger, however. Even the 12 to 14 flights a year NASA is planning by the mid-1990s may be too ambitious.

So the agency is making some small motion toward finding alternatives. The manifest released in October is for a "mixed fleet" of shuttles and conventional rockets in the 1980s and 1990s. With an eye toward the more distant future, the Marshall Space Flight Center is funding a modest study of a heavy lift vehicle called "Shuttle C" (for "cargo"), and the agency is exploring a way to extend the current orbiter's time in orbit. But for all their promise, these are not major programs. Politically and operationally, NASA remains committed to the shuttle for the rest of this century. (See the essay on page 24).

That steadfastness comes at a time when the agency finds itself with the least amount of political clout in its history. Its next major project, the space station, received barely half the amount requested in this year's federal budget. That keeps the patient alive for now, but most observers think the station has little chance of getting the nearly $2 billion it needs to keep on track in the next fiscal year. Without the space station, NASA's program has no direction in the 1990s.

And no long-term plans are likely to be made until the shuttle is flying again. After the failure of a protective "outer boot ring" in the booster nozzle — one of the newly designed hardware elements — during a test firing on December 23, that elusive goal was pushed even further into the future, probably to the autumn, just when the recovery program had seemed to be gathering momentum.

Still, there are other visible signs of resurrection. The shuttle's onboard liquid-fueled engines passed their final certification tests in January, and are ready to go. Construction of a new orbiter vehicle (OV-105) to replace *Challenger* began at a Rockwell International plant in California last August, and will be completed in 1991. By order of Congress, the new shuttle will be named by the nation's school

**"The last time *NASA* flew an all-veteran crew was on Apollo 11."**

children, in a contest to be conducted next school year.

Two thousand Kennedy Space Center workers laid off after *Challenger* have been rehired or replaced, and the work force is back up to its pre-accident level of 15,500. And if NASA's schedule holds, *Discovery* will be rolled to the launch pad this summer for a test firing of its engines.

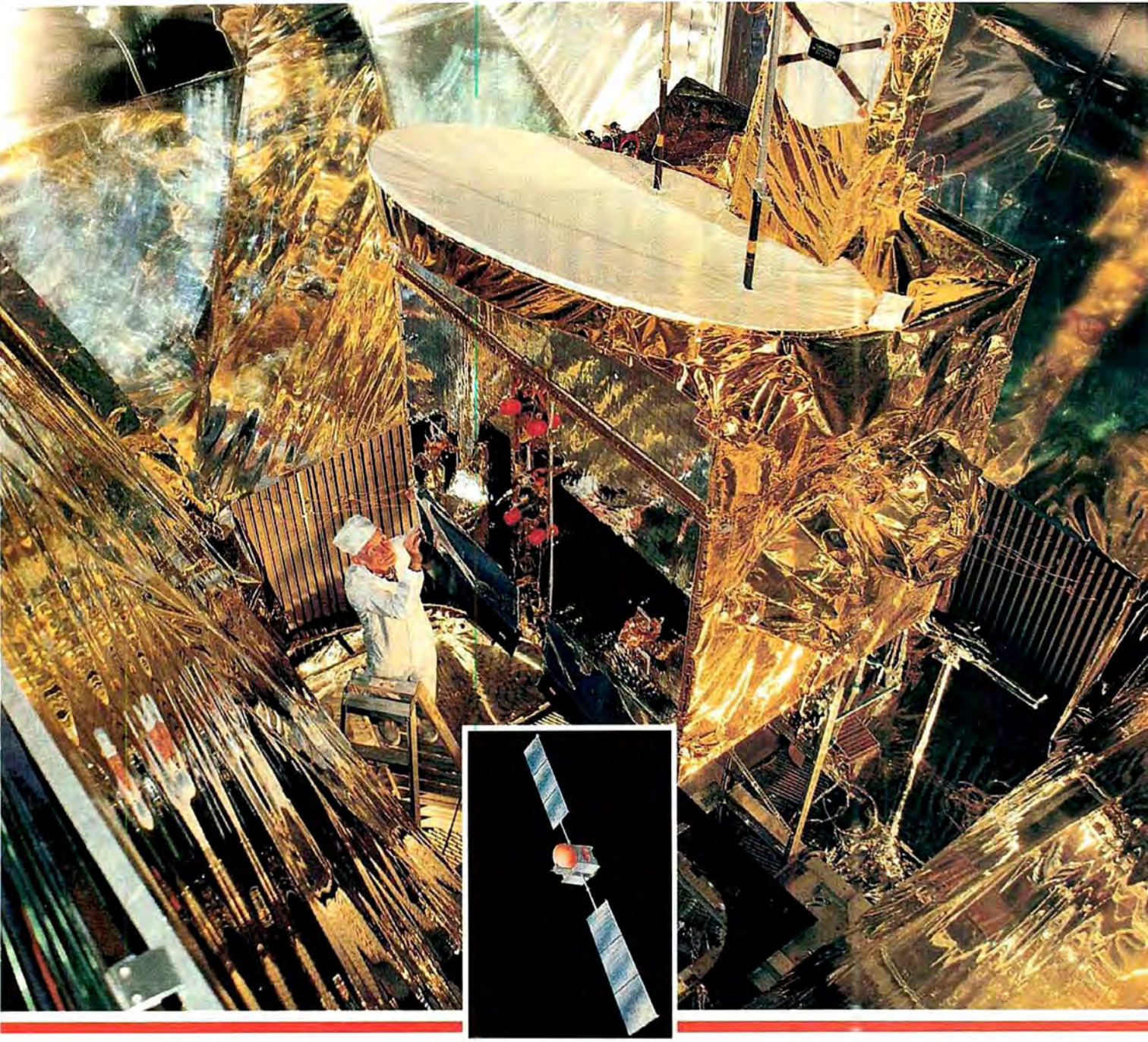
As they perform their final checkouts, the workers will do well to heed astronaut Mike Lounge's remark before a booster test in August: "None of these tests guarantees we'll go on time, but any one of them can guarantee we *won't* go on time." If there are no more surprises, we will see a shuttle launch this year for the first time in more than 30 months, and a landing on the desert lakebed at Edwards Air Force Base four days later.

As with all of NASA's astronaut missions, Rick Hauck and his STS-26 crew had a hand in designing the official crew patch for their upcoming flight. They chose as the central image a bright plume of fire from the solid rockets — representing, says Hauck, a safe launch. In the background are the seven stars of the Big Dipper, one for each of the astronauts lost on *Challenger*.

Sweeping across the field is a vector symbol borrowed from the original NASA logo, which dates back to the Mercury days. Many astronauts still favor this old, round logo nicknamed "the meatball," despite the agency's conversion to a jazzier NASA symbol in the shuttle era. The vector, says Hauck, stands for the crew's reliance on the traditional strengths of NASA.

Finally, as a backdrop for the whole scene, is a sunrise, which Hauck sees as the start of a hopeful future: more shuttle flights, space stations, perhaps even lunar bases and Mars missions.

It's a future that begins the moment *Discovery*'s wheels touch down on the desert runway at Edwards.



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# the SHUTTLE'S UNCERTAIN FUTURE

BY ALEX ROLAND

*A critic argues that, even with the O-rings fixed, the space-plane's problems won't go away.*

*In the two years following the Challenger accident, the space shuttle has been scrutinized like no other project in NASA's 30-year history. In testimony before a presidential commission, in articles and in books, the critics have stepped forward to point out the system's flaws, both technical and human.*

*Alex Roland, now a professor of history at Duke University, was a NASA historian during the eight years leading up to the shuttle's first launch in 1981. Even before Challenger, Roland had written about the compromises, shortcuts and poor management decisions within the space agency that came to light so tragically in 1986.*

*Today he takes an even dimmer view of the vehicle's future. Roland maintains that despite, or perhaps because of the vehicle's technical sophistication, it is inherently flawed as a system for the routine launching of cargo into space, and that the only way out is for NASA to begin working on alternatives immediately.*

*Editor*

PHOTO: TOM USCIAK

NASA has come to expect less of the shuttle. The wonder is that it still expects so much. For the remainder of this century, the shuttle will be the primary launch vehicle of the U.S. space program. It will carry most civilian government payloads and a large percentage of military payloads into orbit, and it will be the workhorse for launching, erecting and servicing the space station scheduled to be placed in Earth orbit in the mid-1990s. By choice or indirection, NASA has left itself with no other launch vehicle capable of bearing this burden.

NASA had a chance to escape this position after the *Challenger* accident. The cost and vulnerability of the shuttle were made manifest by that tragedy, which highlighted in retrospect the sorry performance record of the vehicle in its first five years of flight — the cost overruns, the delays and the failure to live up to design specifications.

Congress has appropriated in the last two years some $5 billion over NASA's previous funding levels to restore the nation's launch capability. The space agency might well have used that funding to develop new vehicles. Instead, it has gambled all on the shuttle, investing more than $2-3 billion in a new orbiter vehicle to replace *Challenger* and spending a yet undetermined sum to get the shuttle fleet ready to fly again. By comparison, the agency invested only a small amount to revive a few expendable launch vehicles — conventional rockets dating back to the 1960s and 1970s — and a lesser amount still for research and development on new launchers.

Is this gamble likely to pay off? What are the prospects for the shuttle when it resumes flying this year or next?

Some things will surely be better than they were before the accident. First, NASA is complementing the shuttle with the few expendable launch vehicles it has on hand, including Delta, Atlas Centaur, and Scout rockets. Instead of the 24 missions a year planned for the shuttle before *Challenger*, the craft will be called on to lift only three missions in 1988, working up to a total of 14 in 1994. While there is no guarantee that it can achieve even this modest schedule, at least there will be back-up vehicles for some payloads should the shuttle experience delays or flight suspensions.

Second, NASA has been adequately funded to conduct an across-the-board survey of the 100-odd technical problems that were on the critical item list before *Challenger*. These were the shortcomings that posed a risk of catastrophic failure. The O-ring seals on the solid boosters were just one of the critical weaknesses on the shuttle that had not been fixed for lack of funds. NASA has an excellent record of mastering these technical problems when it chooses to address them, and there is every reason to believe that the shuttle will be a far safer vehicle when it resumes flying.

The burden of economic competition has also been lifted from the agency's shoulders. The shuttle will not be used for commercial launches in the foreseeable future, meaning that NASA will no longer have to subsidize shuttle flights to remain competitive in the world market, and it will not have to push its launch schedule to hold down overhead costs and meet the demands of commercial users.

Furthermore, it is unlikely that NASA will soon revive the excursion policy that characterized the first phase of shuttle operations. For a good while, at least, we are likely to be spared senators in space, and congressmen in space, and Saudi princes and teachers and journalists in space. Without these publicity stunts, NASA is less likely to repeat the error of Congressman William Nelson's flight in December 1985. After several launch delays, NASA was reportedly inclined to cancel this flight, save that Congressman Nelson, Chairman of the House Space Science and Applications Subcommittee, which passes on NASA's budget, insisted that it go ahead. The flight launched late and returned late, adding to the scheduling pressures on the next flight: *Challenger*'s 51-L mission in January 1986.

Finally, each orbiter vehicle is an improvement over its predecessors. The one being built to replace *Challenger* will be the lightest and most capable yet developed. It has improved on-board computers, new carbon-carbon brakes and other improvements in design to increase safety and

decrease vehicle weight. Many of the new features are also being installed in existing orbiters. These craft will carry more payload more safely than the earlier versions did.

Many shuttle problems, however, defy the quick fix. They are inherent in this particular technological system and will not go away. There is no prospect, for example, that the refurbished shuttle fleet will come significantly closer to achieving the performance goals set for the craft before its first flight in 1981. They will not lift the 65,000 pounds of payload for which they were originally designed. They will not turn around from landing to re-launch in two weeks. They will not be able to land at any 10,000-foot runway. In fact, it is not yet clear that they will even be able to land at the runway at the Kennedy Space Center that was built specifically to accommodate them. Troublesome brakes and landing gear forced their diversion to the still safer runway at Edwards Air Force Base in California, where they will no doubt continue to land until NASA has a high degree of confidence that it has the landing problems solved.

It also seems unlikely that engineers will be able to improve on the life expectancy of the major components of the shuttle. The orbiter vehicles were designed for 100 flights, the main engines for 55 flights, and the solid rocket boosters for 20 flights. Operating experience suggests that the main engines will never approach that standard. Wear and tear on the boosters caused by parachuting them into the ocean and retrieving them was seen as a contributing cause to the rocket failure that caused the *Challenger* accident.

While the orbiters may be technically capable of surviving 100 flights, even that achievement is clouded by the extensive refurbishing they require. It may well be more expensive to repair, re-fit and return the orbiters to the launch pad 100 times than they are worth in the first place.

Surely nothing in the foreseeable future is likely to bring the shuttle anywhere near the cost goals that were set for it at the outset. Designed to carry payloads into orbit for less than $2,000 a pound (in 1987 dollars), the refurbished shuttle will require, by a recent estimate, $6,800 for each pound it delivers to orbit.

Some prospects for the shuttle are quite simply worse than they were before the accident. NASA will face a three-year backlog of missions when it resumes flights; all will have to get in line behind the military. The Air Force experienced an 18-month hiatus in its own heavy launches, beginning with the explosion of a Titan rocket just three months after *Challenger*. The drought was relieved only when another Titan inserted a reconnaissance satellite into orbit last October. In the interim the United States was relying on only one major reconnaissance satellite in orbit. Many other military missions have backed up as well, and the military commitment to revive production of conventional expendable rockets and begin development of new ones will not bear mature fruit for many years.

One-third of the shuttle flights for the next decade are to

NASA ARTWORK BY SARA LARKIN

**The shuttle program may survive the scheduling problems for which it is headed, but sooner or later the economics of spaceflight will catch up with it.**

be military missions. If NASA has any autonomy left at all in conducting the shuttle program it will surely be severely compromised by the ability of the military to claim priority for its missions. A veil of secrecy will fall over NASA operations in the coming years, complicating operations at the Kennedy Space Center and imposing on flight personnel an awkward and uncharacteristic gray-out of press coverage. To make matters worse, NASA will be forced to subsidize these military flights from its own budget. NASA will charge the Department of Defense only $95 million for a shuttle launch when flights resume. The real cost to the agency will be two or three times that amount. Other NASA programs will be taxed to make up the difference.

NASA has decided to erect the space station, its next major project, relying almost entirely on the shuttle. Although the numbers change almost daily, by recent estimates it will take 19 shuttle flights to erect the station. Then it will require as many as two-thirds of the remaining flights in the following years to exchange and resupply the crews. NASA is under growing pressure to develop and use expendable rockets to launch and resupply the station, but so far has resisted, sticking instead to its original commitment to rely exclusively on the shuttle.

Pending a final decision on whether an emergency escape vehicle will be added to the shuttle, the agency will also keep at least one vehicle available at all times for crew rescue. Combine the projected flights dedicated to the station with the number of military launches already spoken for, and NASA has obligated all its shuttle flights for the next ten years or more. And all of these calculations assume that there are no losses or serious delays in the shuttle launch schedule.

When flights resume, NASA will of necessity be extremely cautious in launch decisions. The press, embarrassed by its failure to anticipate the problems in the shuttle program before *Challenger* and then antagonized by the stonewalling at NASA in the wake of the accident, will be scrutinizing and second-guessing the agency as never before in its history. Individual NASA officials, not wanting to be the one responsible for the next accident, will most likely err on the side of caution, and more officials than ever will be in a position to halt a launch. The contractors who work hand-in-glove with NASA will be equally cautious. NASA can survive, even prosper from, one accident. A second one soon would jeopardize the entire civilian space program as it is now constituted.

This situation, it should be noted, is almost entirely of NASA's own doing. In spite of protests that the agency's problems arise from unstable and inadequate funding or indifference from the White House, the fact is that through four administrations and seven Congresses NASA has been given a steady annual budget that has not deviated significantly from a constant-dollar value of about $7 billion (in 1986 dollars). Within that budget the agency was given remarkable latitude to design and conduct the civilian space program. The sequence of projects from Apollo to the shuttle to the space station and ultimately on to Mars was laid out in the late 1960s; agency officials refer to each as "the next logical step" in space. NASA chose those steps and it has no one to blame but itself if they have proved to be false.

What, then, are the prospects for the shuttle when it resumes flying? Technically, it will be a sounder, safer vehicle than before. In fact, it will likely be the safest launch vehicle in the world. For a while, at least, it ought to enjoy the highest success rate. The other side of that coin, however, is that it will also be the most expensive launch vehicle in the world, the most vulnerable to delays, and the most susceptible to deterioration of its components.

NASA will most likely begin cautiously, treating the early flights as tests. As pressure mounts to launch backlogged weather satellites, Earth resources satellites and scientific missions, NASA will find itself once more under intense

NASA ARTWORK BY RON COBB

**When it resumes flying, the shuttle will likely be the safest launch vehicle in the world. . .The other side of that coin, however, is that it will also be the most expensive launch vehicle in the world.**

scheduling pressure. Low-priority missions will be scrubbed and sent overseas for launching, to Europe and Japan, and perhaps even to the Soviet Union. Commercial launchers in the United States could relieve this burden somewhat, but they are still years away from what in any event is a very risky enterprise. Governments have been hard pressed to develop launch capabilities; it is still not clear that private enterprisers can find a niche in this high risk, capital-intensive competition. The insurance alone will pose an insurmountable obstacle to many private ventures.

The shuttle program may survive the scheduling problems for which it is headed, but sooner or later the economics of spaceflight will catch up with it. NASA now estimates that it can fly a shuttle mission for less than $100 million. Former agency administrator James Beggs admitted in 1985 that it cost $120 million per flight then — the equivalent of $138 million today. And that estimate did not include such items of overhead as running the Kennedy and Johnson Space Centers, the two NASA facilities most involved with shuttle operations. No one knows yet what the next shuttle flight will cost. A conservative estimate is $200 million. A more realistic estimate is $300 million, and it will probably exceed even that. Yet NASA continues to use the $100 million figure in projecting such future expenses as launching the space station.

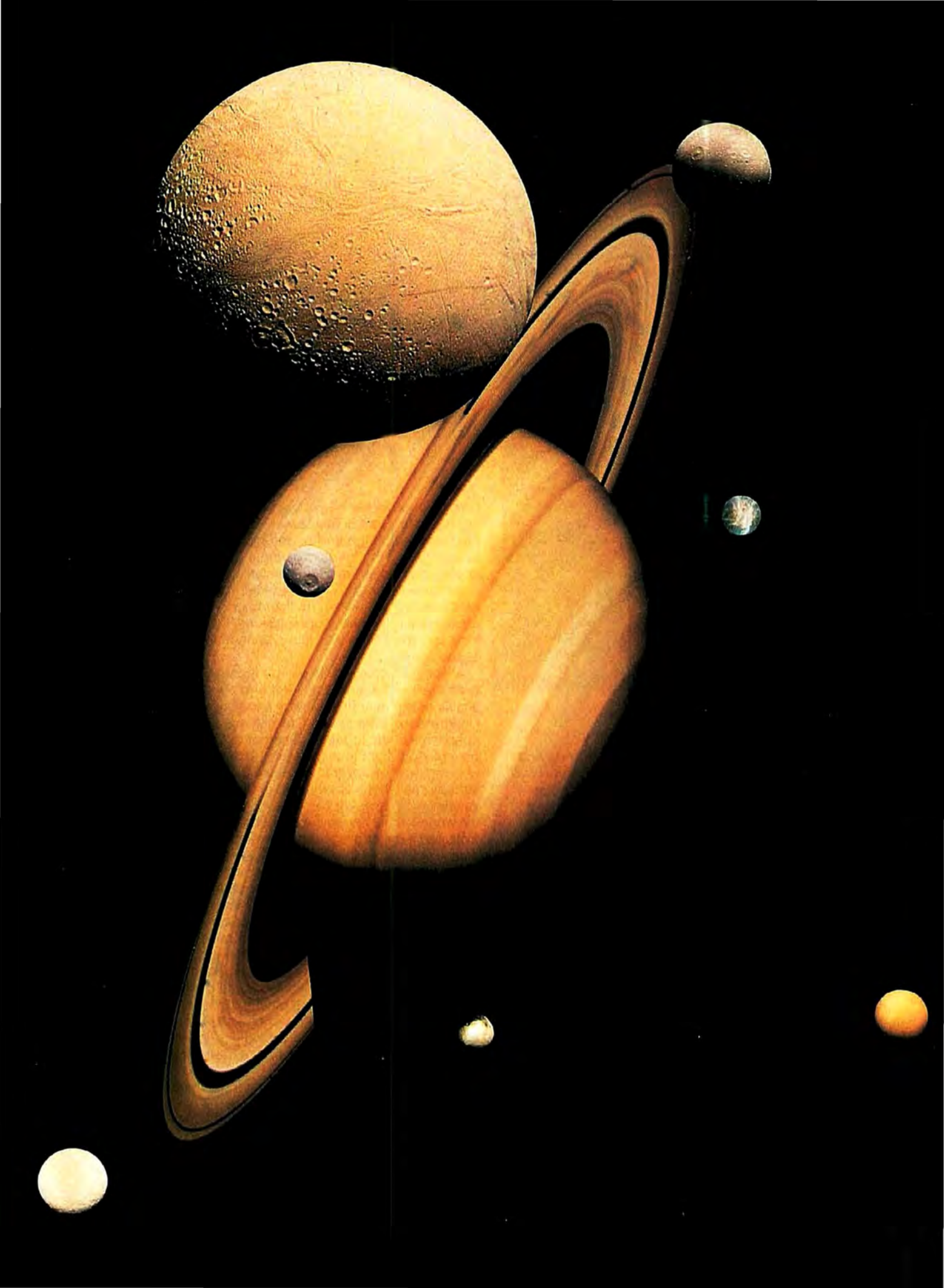
The more shuttles NASA launches, the deeper in the hole it will get. As it did in the first half of the 1980's, the shuttle will start to eat up the rest of the NASA budget. Other programs will be cut back or cancelled. Pressure will rise again to avoid costly launch delays. Technical problems will be ignored or deferred, as they were before *Challenger*, or the funds to fix them will come out of the operations budget, raising costs still higher.

Yet none of this will stop the bleeding. If anything, the problems will get worse. As the major shuttle components experience more and more missions, their failure rate will increase, most likely well in advance of their designed life expectancy.

At some juncture NASA will be faced with the same dilemma it encountered in 1984 and 1985: admit that the shuttle program is prohibitively expensive and go back to Congress for more funding, or bull ahead and pray that the spacecraft holds together. One hopes that the agency will be more forthright than it was in 1985, but one also wonders why we have to go down that road at all. We can already see where it leads. Why is NASA building most of its launch capacity for the remainder of this century around the world's most expensive launch vehicle? Why hasn't it instituted a major program to develop a new generation of launch vehicles? More importantly, what can the agency do to escape the trap it has laid for itself?

The answer is in diversity. The shuttle is a magnificent technological achievement, one or two generations ahead of anything else in the world. Its capabilities, however, far exceed the demands of most launch missions; we are sending a Cadillac limousine to do the job of a Chevy coup. We need a diversified stable of launch vehicles, so that for any particular mission we could choose the rocket that is most appropriate and most economical for the job. In some few cases, like retrieval of a satellite or the orbiting of Spacelab, this might be the shuttle. In most cases, however, a cheaper and less risky expendable launch vehicle would suffice.

The other vehicles in the stable should come from revival of existing rockets, which NASA is pursuing, and development of new cost-effective launch vehicles, in which NASA is dragging its feet. Part of the funding for this research could come from cancellation of the replacement orbiter, which is simply not needed. Pursuit of a policy like this requires nothing more than a recognition of the shortcomings of the shuttle and a commitment to a practical and efficient space program in the future.



*Voyager 2 is the most successful explorer in history. So why should its mission have to end?*

# BEYOND NEPTUNE

NASA ARTWORK BY DON DAVIS

*BY JOEL DAVIS*

At 9:00 P.M., Pacific daylight time on August 24, 1989, the U.S. space program will chalk up another historic milestone, as the hardy Voyager 2 space probe flies past the distant planet Neptune. The spacecraft will come within 2,600 miles of the top of Neptune's atmosphere. About five hours later it will fly within 24,000 miles of the planet's giant moon Triton. That close encounter will be the climax of Voyager 2's epic mission of Solar System exploration, but it will not be the end of its journey. It marks instead the beginning of a new mission. Voyager 2 is heading for the stars.

The journey began in 1977 with a launch atop a Titan-Centaur rocket from the Kennedy Space Center in Florida. In the four years after that, Voyager 2 and its companion Voyager 1 each made close flybys of the giant planets Jupiter and Saturn. The two probes returned thousands of spectacular images of those worlds, their rings and their moons. Voyager 1's trajectory after Saturn took it up and out of the plane of the planets. Voyager 2, though, was boosted by Saturn's gravity onto a path that would take it to another destination. On January 24, 1986, it became the first space probe ever to visit the planet Uranus, more than 1.6 billion miles from Earth.

That flyby was a spectacular success. Voyager 2 returned incredible photographs of Uranus, its peculiar, dark rings and even stranger five major moons. The images of tiny Miranda were especially mind-boggling. Along with the photos, Voyager 2 also discovered ten smaller moons of Uranus and dozens and perhaps hundreds of new ringlets and ring arcs, and reported back on the bizarre Uranian weather.

PHOTO: NASA

The probe is now about 500 million miles from Neptune and closing, traveling at a velocity of 11 miles per second, relative to the Sun. For the remainder of this century, Neptune will be the outermost planet of the Solar System. Most of the time that honor goes to tiny Pluto and its moon Charon, but Pluto's egg- shaped orbit has brought it closer to the Sun than Neptune until 1999.

Voyager 2 is very precisely targeted to fly over the Neptunian north pole. The planet's powerful gravitational field will then bend the spacecraft's path like a hairpin and send it streaking past Triton. From there, assuming it survives the Neptune encounter in good health, the probe will head down and out of the Solar System, into the great darkness of interstellar space.

Voyager 2 is by no means the only manmade object headed into that great beyond. So is Voyager 1, and the Pioneer 10 and Pioneer 11 probes launched before them. All four have gotten huge boosts in velocity from their close encounters with Jupiter and Saturn. In some cases those "gravitational slingshots" were deliberately planned and carefully calculated. The primary purpose was to get a "free ride": extra velocity to carry the spacecraft to the next target. Without the gravity boosts, it would have taken more than a decade to get from just one outer planet to the next.

**Having passed Jupiter, Saturn (at left, with moons) and Uranus, Voyager's next stop is Neptune (above) in 1989.**

Voyager 2 will be the only one of these far travelers to make the entire "Grand Tour" of the four outer "gas giants" — Jupiter, Saturn, Uranus and Neptune — a feat it will accomplish in just 12 years. The spacecraft has already traveled a total of more than 3.8 billion miles through the Solar System. Without doubt, Voyager 2 is the greatest explorer in human history.

Why, then, turn your back on a prize-winning spacecraft just because it has run out of planets to explore? After the Neptune encounter, Voyager 2 will continue to send back data. For that reason, Voyager project managers at NASA's Jet Propulsion Laboratory in Pasadena, California are making plans for a Voyager Interstellar Mission, or VIM.

NASA's giant antenna dishes will be able to receive data from Voyager 2 through the year 2165, by current estimates. By then the probe will be 620 Astronomical Units, or AU, from Earth. That's 620 times as far from home as Earth is from the Sun — a total distance of 57 billion miles.

But other factors will end Voyager's useful life long before its signals get too faint for the antennas on Earth to hear. Charles Kohlhase and his team in the Voyager Mission Planning Office have sorted out the limitations. For example, the probe's Sun sensor

**The psychological effects of a photographic "view of the Solar System from interstellar space" could be immense.**

helps keep the spacecraft properly oriented in space. The sensor may no longer be able to detect the faint solar disk after the year 2029.

Fuel is another limitation. Voyager 2 uses hydrazine fuel for the small thrusters that keep it properly pointed at the Earth and the Sun. The spacecraft could have enough hydrazine to last it through 2020, but not for much longer. Then there's the matter of electrical power. Kohlhase estimates the spacecraft will only have enough onboard electrical power to keep its instruments and computers running through the year 2015, depending on how much power is used. "This turns out to be our real limit on how long Voyager 2 will be able to send back information," says Kohlhase.

Even with these limitations, that still leaves about 26 years for Voyager 2 to send back data on whatever is out there beyond the planets. Assuming nothing wretched happens at Neptune, the interstellar mission is on. What will it entail?

It will primarily be a "fields and particles" mission, scouting the vast ocean of radiation and energy beyond the planets. The spacecraft will spend most of its time sampling this so-called "extrasolar" environment, sniffing out cosmic rays, charged particles, various kinds of plasmas and plasma waves, and magnetic fields. Of the eleven instruments on board Voyager 2, five and possibly seven will play a role in the interstellar mission. They include such devices as the magnetometer and the cosmic ray detector. The ultraviolet spectrometer and TV cameras will also be used at times.

Some of the scientific objectives include observing and measuring

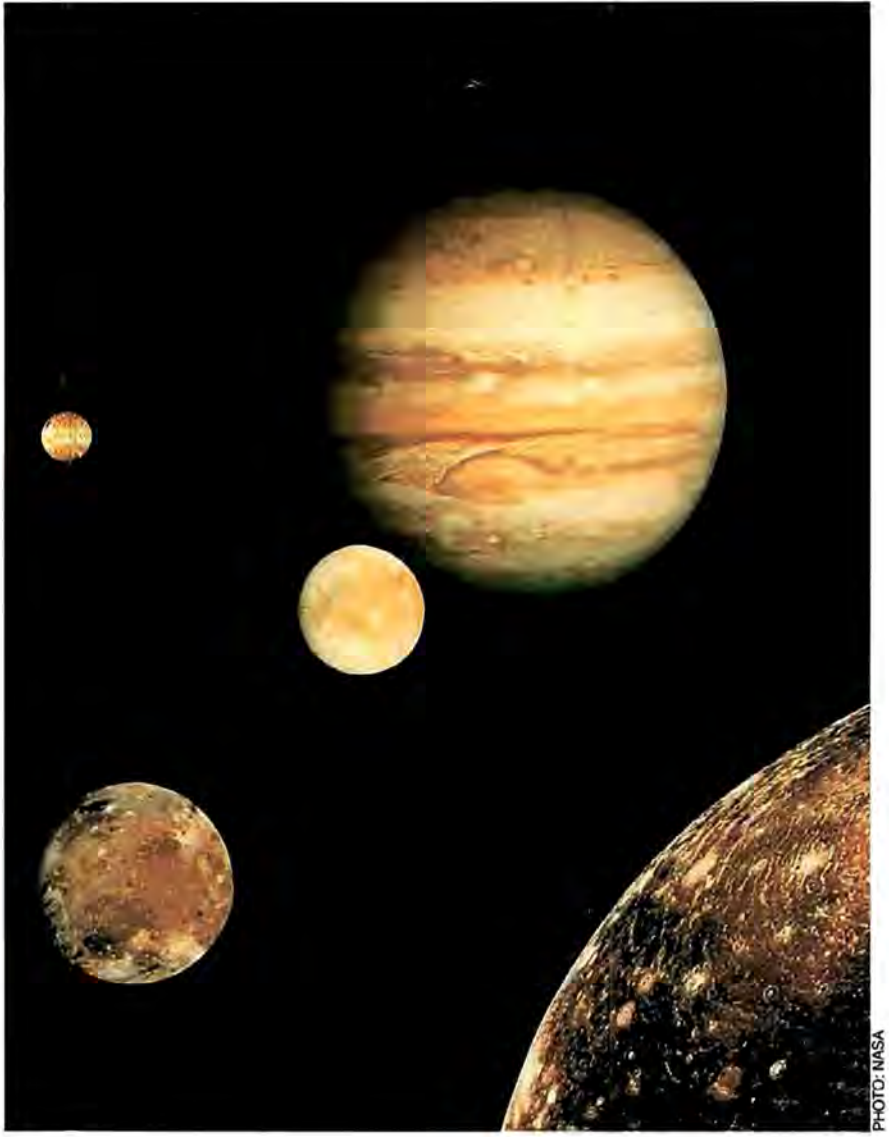
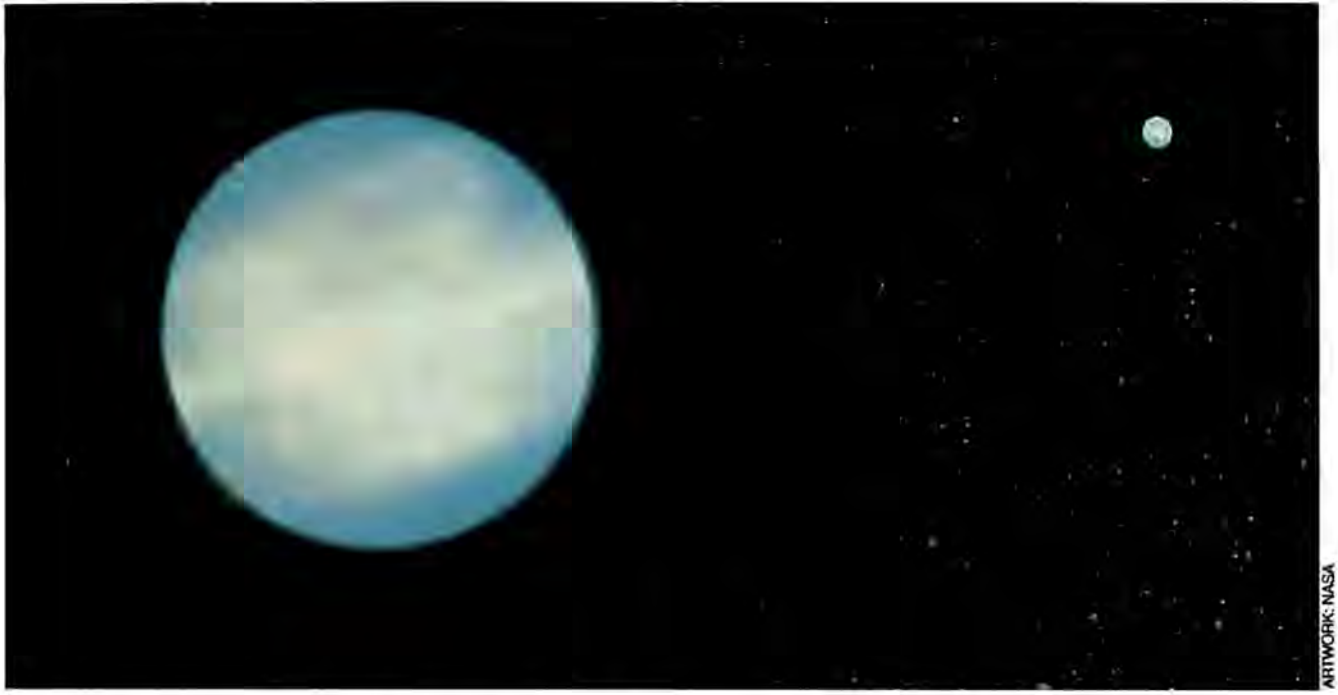


PHOTO: NASA

PHOTO: NASA

**Voyager's picture album includes travel shots of giant Jupiter (above, with its four large moons Io, Ganymede, Europa and Callisto) and Uranus, photographed as a crescent by Voyager 2 as it left the planet behind in January 1986. Voyager may be able to snap a family portrait of the planets in one of its last photos before heading for the stars.**



ARTWORK: NASA

reversals of the Sun's magnetic field, and learning more about how the solar wind — the torrent of radiation streaming in all directions from the Sun — changes at great distances from its source.

Voyager will also be searching for low-energy cosmic rays and learning more about how subatomic particles are accelerated to great velocities in extrasolar space. Other instruments will be on the lookout for hydrogen and helium coming toward us from interstellar space, and also for evidence of an interstellar wind of gas and subatomic particles.

One major goal is to try to locate the boundary where the outgoing solar wind actually comes into contact with the larger ocean of interstellar gas and dust. This boundary, never before seen, is called the heliopause. W.R. Webber of the Max Planck Institute for Extraterrestrial Physics in West Germany has recently used Voyager data to make a guess at the location of the heliopause. He thinks it is about 46 to 56 AU from the Sun. Scientists at the University of Southern California agree. They have calculated that Pioneer 10 might meet the heliopause as soon as 1990, at a distance of 50 AU. If that's correct, Voyager 2 will pass the boundary line long before its electrical power gives out.

Voyager 2 will have other goals besides these. It will use its plasma wave instrument and planetary radio astronomy instrument to try to detect radio waves coming from the Sun. The probe has been recording these radio bursts for years, but Voyager investigators want to see what the bursts look like in a region far removed from any planet.

Scientists will also continue to use the probe as a tiny astronomical observatory. An onboard spectrometer has already examined the ultraviolet spectra of several distant stars. Those observations will continue. Voyager project managers are considering increasing the data return rate for the ultraviolet spectrometer during the first few years of the interstellar cruise. That would improve the quality of the data the instrument sends back.

Perhaps the most intriguing experiments to armchair explorers make use of the spacecraft's TV cameras. Voyager 2 will take long-exposure pictures of specific areas of distant star fields. Astronomers will then compare the positions of certain stars as seen from Voyager with images taken from Earth. Any apparent shift in position, called a "parallax shift," between the two photos would allow an accurate measurement of the distance of those stars from Earth. This new trick in the old and honorable branch of astronomy called astrometry could lead to more accurate "yardsticks" for measuring interstellar distances.

Voyager's cameras are not nearly powerful enough to see planets around other stars. One imaging experiment, however, would do something similar to that. Among its proponents are astronomer and Voyager imaging team member Carl Sagan, who also helped create the Voyager record of Earth sights and sounds included on each spacecraft as a message to alien civilizations. Sagan wants to take a long-exposure picture of our Solar System.

Such a picture is possible, but difficult to pull off. If it were attempted at all, it could be done with either Voyager 1 or Voyager 2. New and untried maneuvers for Voyager 2 have often been first tested on Voyager 1. On the other hand, Voyager 2 will have no more planetary flybys after Neptune, so the Solar System image could be taken with its cameras without jeopardizing the main mission. Scientists will probably use the probe's narrow-angle camera, since it is more sensitive for imaging faint objects. The wide-angle camera, however, would photograph a larger area of the sky and therefore perhaps more planets.

In either case, some delicate maneuvering is required. "You can't

*continued on page 61*

## NEAR STAR ENCOUNTERS FOR VOYAGER 2 AFTER NEPTUNE FLYBY (AUG. 25, 1989)

| CLOSEST APPROACH TIME (YEAR) | CLOSEST APPROACH DISTANCE (LIGHT-YRS.) | STAR NAME |
|---|---|---|
| 8,571 | 4.026 | Barnard's Star |
| 20,319 | 3.209 | Proxima Centauri |
| 20,629 | 3.467 | Alpha Centauri |
| 23,274 | 4.647 | Lalande 21185 |
| 40,176 | 1.653 | Ross 248 |
| 44,492 | 5.574 | DM-36 13940 |
| 46,330 | 2.766 | AC+79 3888 |
| 129,084 | 5.752 | Ross 154 |
| 129,704 | 3.443 | DM+15 3364 |
| 296,036 | 4.323 | Sirius |
| 318,543 | 3.917 | DM-5 4426 |
| 442,385 | 6.717 | 44 Ophiuchi |
| 957,963 | 6.615 | DM+27 1311 |

Data courtesy Robert Cesarone, Jet Propulsion Laboratory.

**Until Voyager reaches Neptune and its moon Triton next year, this artist's view is the best we have.**

*The view from the Moon is more than just pretty. It can change your life.*

BY FRANK WHITE

*The "Overview Effect," writes Frank White, is a profound change in perception experienced by those lucky few who have seen the Earth from space, surrounded by the black void and with no national borders. The effect — which the author believes has deep political and social consequences for humanity's future — is felt not only by astronauts and cosmonauts, but also by those who participate imaginatively in their adventures. According to this excerpt from White's book, perhaps none have felt it so strongly as the 24 men who have left the bonds of Earth's gravity to journey to the Moon.*

For all the impact of seeing our planet from an orbit of 100 to 200 miles, astronauts or cosmonauts at that altitude do not see the whole Earth, but rather large sections of its surface. Not until 1968, when Apollo 8 went to the Moon, were astronauts able to view the whole Earth.

Eugene Cernan, who went to the Moon twice on Apollo 10 and Apollo 17 and was the last human to leave the lunar surface, put it this way: "Without question, when you are in Earth orbit, you get a new perspective, but you don't have time to get philosophical about it ... When you leave Earth orbit, all those coastlines and rivers you see in orbit become oceans and continents. You can see from pole to pole and ocean to ocean without even turning your head."

# LOOK BACK

PHOTO NASA/JSC

Lunar missions are unique in the history of space exploration because they include every important element of the spaceflight experience. Astronauts going to the Moon orbit the Earth, leave low Earth orbits, see the whole Earth, and have longer missions. Some even conduct a spacewalk on a "planet" other than Earth.

Russell L. ("Rusty") Schweickart, selected in 1963 in the third group of American astronauts, had not flown in space prior to Apollo 9 in 1969, when he tested the Apollo space suit during a spacewalk in Earth orbit. His comments on the experience illustrate a fundamental change in astronaut awareness that began with the later orbital and lunar missions. In particular, he sees that the division among nations, the "parts" of which we are so aware on Earth, disappear and become unimportant from orbit. He also sees that these insights change the viewer's sense of his identity.

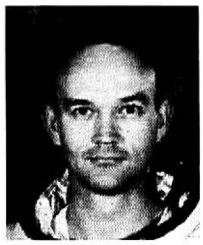
Schweickart may be unique. With the exception of Edgar Mitchell, Apollo 14 astronaut and founder of the Institute of Noetic Sciences, few astronauts seem to have been as deeply affected by spaceflight as he.

Schweickart's experience is also special because of his active efforts to communicate it to the public and through the Association of Space Explorers, an organization of astronauts, cosmonauts and other space travelers he co-founded in 1985. I asked Schweickart what happened when he told others about his experience. Did they change as well? His answer was that they do. "In some cases, nothing is transmitted at all. Often, it is so profound and immediate that it scares me."

# IN WONDER

Rusty Schweickart

Gene Cernan



Michael Collins

Edgar Mitchell

ALL PHOTOS NASA

Twenty-four astronauts went to the Moon. They either landed there, orbited the Moon, or flew by it and returned to Earth. Of those, twelve walked on the lunar surface. The astronauts and cosmonauts who have gone into space make up an infinitesimal percentage of the planet's population. Those who have gone to the Moon represent 13 percent of all space travelers, and those who have walked on the Moon are six percent of the total. The lunar astronauts constitute one of the most exclusive minorities in the world, and the "Moonwalkers" are an elite within an elite.

Not surprisingly, it also appears that the Apollo astronauts have had some of the most profound experiences in space. The astronaut in Earth orbit has a new and different relationship with the Earth, but it is still the primary point of reference in the universe as a whole. By contrast, the lunar astronaut sees the Earth grow smaller each day of the voyage, and enters the gravitational field of another planetary body. For a brief period, instead of relating primarily to the natural system Earth along with several billion other humans, the tiny human system known as the Apollo crew relates more directly to the Moon.

As Rusty Schweickart put it in his 1977 film commentary *No Frames, No Boundaries*, the lunar astronauts see the Earth very differently from those who go into Earth orbit.

> A little later on, your friend ... goes out to the Moon. Now he looks back and he sees the Earth not as something big, where he can see the beautiful details, but ... as a small thing ... The contrast between that bright blue and white Christmas tree ornament and the black sky; that infinite universe, really comes through.

The orbital astronaut sees the Earth as huge and himself as less significant. The lunar astronaut sees the Earth as small and feels the awesome grandeur of the entire universe. This brings home the meaning of Gene Cernan's view that there are two different space programs, one in Earth orbit and the other beyond.

Both programs change the astronaut's perception of the Earth and of his or her own identity, but in quite different ways. In his film commentary, Schweickart said:

> The Earth is so small and so fragile and such a precious little spot in that universe that you can block it out with your thumb. And you realize on that small spot, that little blue and white thing, is everything that means anything to you--all history and music and poetry and art and death and birth and love, tears, joy, games, all of it on that little spot out there that you can cover with your thumb. And you realize from that perspective that you've changed, that there's something new there, that the relationship is no longer what it was.

Gene Cernan uses similar language: "You ... say to yourself, 'That's humanity, love, feeling, and thought.' You don't see the barriers of color and religion and politics that divide this world. You wonder, if you could get everyone in the world up there, wouldn't they have a different feeling?"

Michael Collins, who orbited the Moon in July 1969 while Neil Armstrong and Edwin E. ("Buzz") Aldrin Jr. were the first humans to walk on it, also wrote about the experience of being "100,000 miles out, to look out four windows and find nothing but black infinity, to finally locate the blue and white golf ball in the fifth window, to know how fortunate we are to return to it."

Seeing the Earth from the Moon intensifies the awareness that there are no real boundaries between us on Earth. Collins wrote of this in his 1974 book, *Carrying the Fire:*

> I think the view from 100,000 miles could be invaluable in getting people together to work out joint solutions, by causing them to realize that the planet we share unites us in a way far more basic and far more important than differences in skin color or religion or economic system. The pity of it is that so far the view from 100,000 miles has been the exclusive property of a handful of test pilots, rather than the world leaders who need this new perspective, or the poets who might communicate it to them.

Collins realizes that having a few people see the planet from 100,000 miles is only the beginning of the experience for the society. When I interviewed him in 1986, the former astronaut elaborated on this last point by saying that the best crew for an Apollo mission would be a "philosopher, a priest, and a poet." Then he added, "Unfortunately, they would kill themselves trying to fly the spacecraft."

In a 1985 article in TV Guide, Gene Cernan wrote about the power of seeing the Earth from that great distance:

> When I was the last man to walk on the Moon in December 1972, I stood in the blue darkness and looked in awe at the Earth from the lunar surface. What I saw was almost too beautiful to grasp. There was too much logic, too much purpose — it was just too beautiful to have happened by accident. It doesn't matter how you choose to worship God ... He has to exist to have created what I was privileged to see.

Thus, the lunar astronaut, in seeing so much more of the Solar System and the universe than the orbital astronaut, begins to sense that an

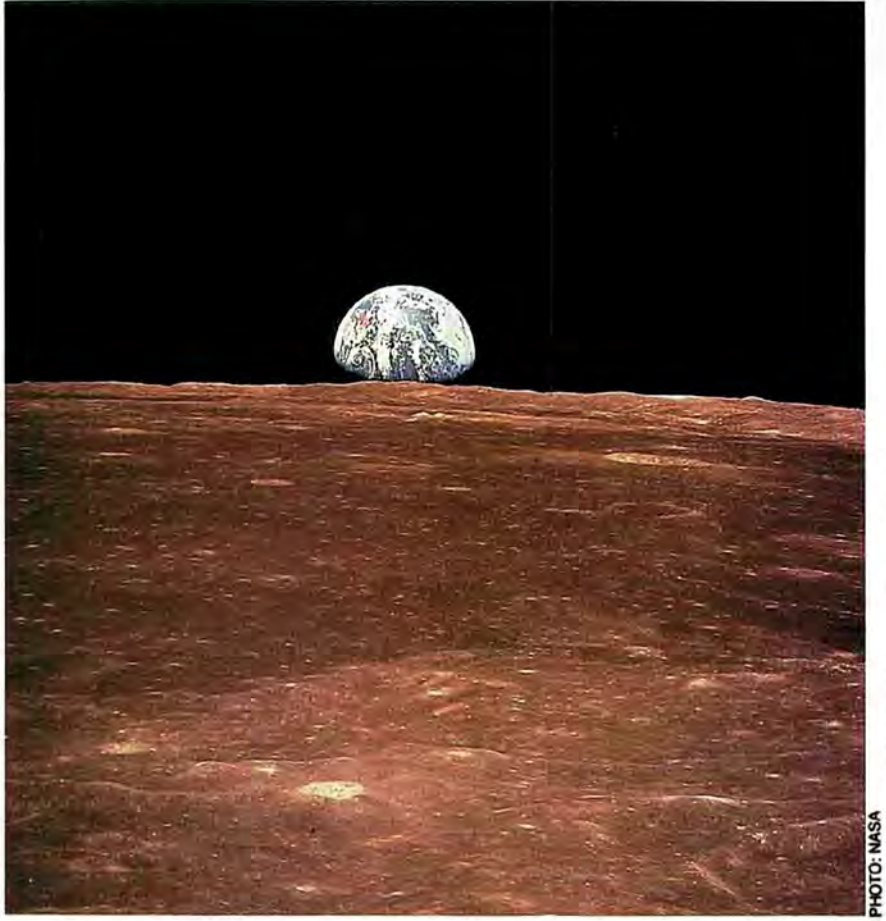


PHOTO: NASA

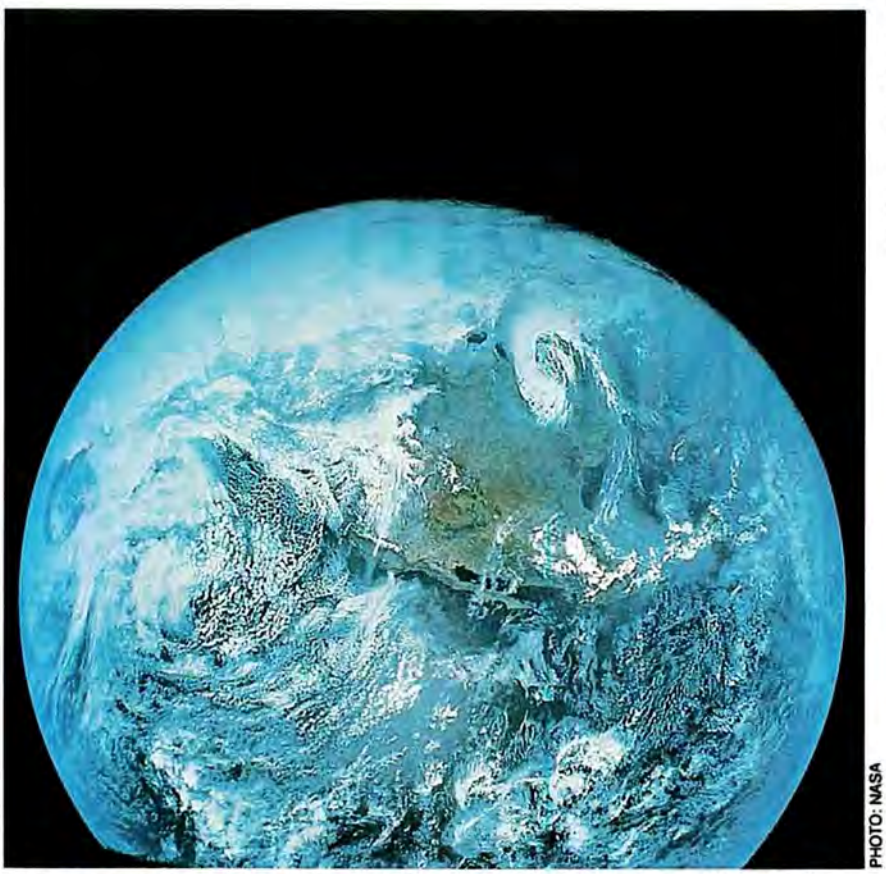


PHOTO: NASA

**Apollo astronauts (from left, opposite page), Rusty Schweickart, Gene Cernan, Michael Collins and Edgar Mitchell had different personal experiences in space, but all agree that the farther out from Earth you go, the more profound the experience.**

underlying purpose may be behind it all. This is the essence of a "new psychology for a new civilization," a recognition of what is important through an understanding of who we are and where we are in the universe as a whole.

Apollo 15 astronaut Jim Irwin (whose expeditions to find Noah's Ark have kept him in the public eye in recent years) and others have suggested that it is the contrast between the Earth and the Moon that jolts astronauts into a different awareness. The Earth is a water planet, beautiful, full of life and hospitable to life.

Perhaps the unique lunar expedition experience belongs to Edgar Mitchell, who flew on the Apollo 14 mission and was the sixth man on the Moon. Just as Rusty Schweickart's experience is a model for the Overview Effect, Mitchell's is a good example of the Universal Insight. Significantly, the experience occurred while Mitchell was gazing at the Earth. According to an article in Omni magazine in 1984:

> On the way back from the Moon, while contemplating the Earth, Mitchell had a "peak experience or a religious experience, depending on what word you want to use." It was an "explosion of awareness, an aha! a wow!" It was, apparently, what a religious person would call a revelation.
>
> He came to realize that the universe is made up of spirit and matter but that they are not separate. The bridge is consciousness. God is something like a universal consciousness manifest in each individual, and the route to divine reality and to a more satisfying human, material reality is through the human consciousness.

When I spoke with him more than two years later, Mitchell said that he could now articulate his

*continued on page 62*


*This cosmonaut artist draws inspiration from his own frequent travels in space.*

## THE VISIONS OF

# VLADIMIR DZHANIBEKOV

*BY LES DORR, JR.*

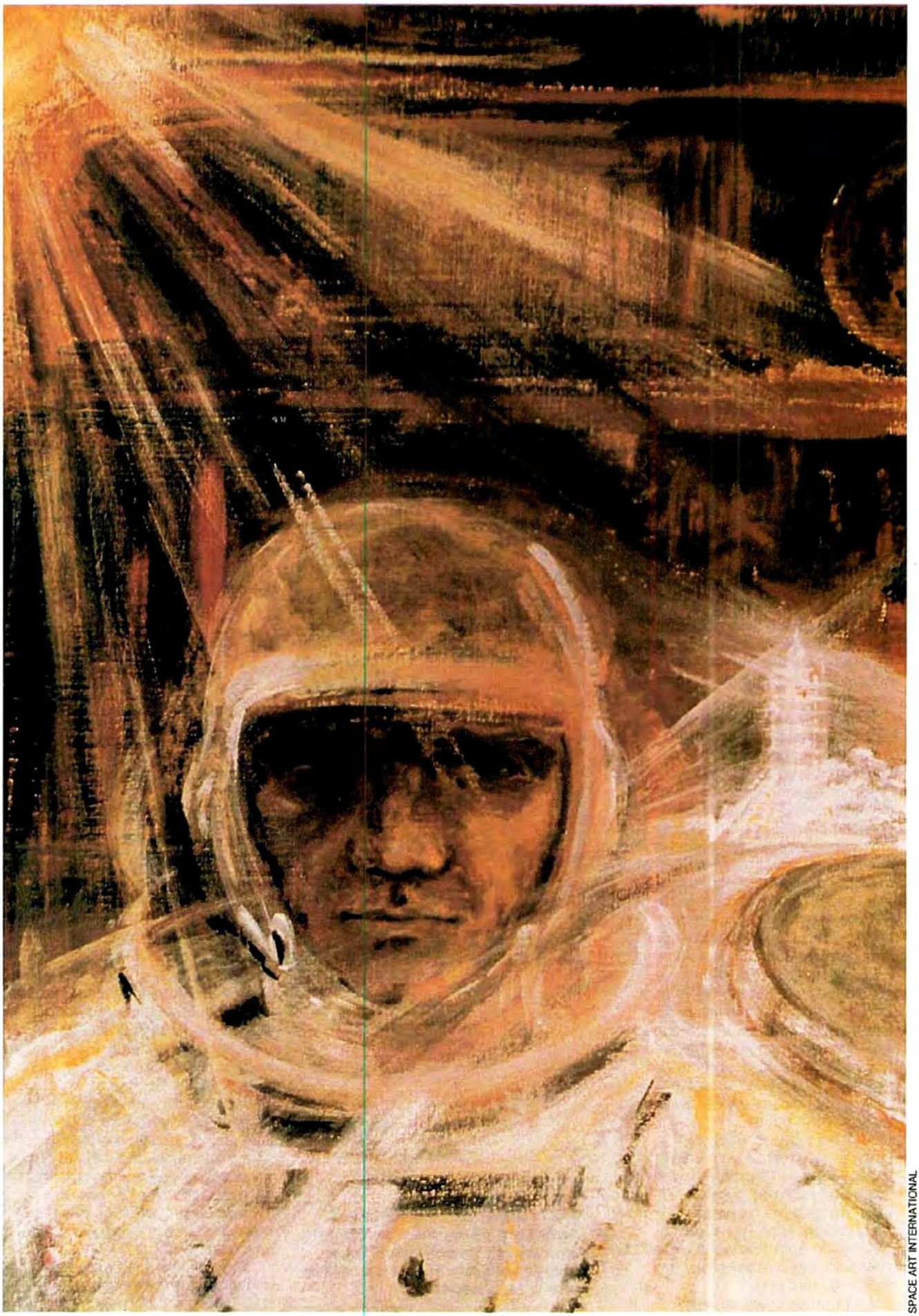
In official portraits, Vladimir Aleksandrovich Dzhanibekov appears the very model of a modern major general. The rows of medals and decorations on his Air Force dress blues testify to his exalted status as a seasoned veteran of air and space. If Hollywood ever wants a Soviet starship captain for the *Star Trek* movies, Dzhanibekov should win the role hands down.

But there is another side, rarely seen by those outside Dzhanibekov's family and a small circle of close friends. This five-time spacefarer, Cosmonaut First Class, twice Hero of the Soviet Union, is also an accomplished artist who successfully brings to life in his paintings the profound connection between Earth and space.

Dzhanibekov, 45, has been interested in art since his childhood. He grew up in a small village near Tashkent in Uzbekistan, for centuries a focal point for artists and artisans. "At first I did caricatures, sketches of my family," recalls the cosmonaut, speaking mostly through an interpreter even though his own English is quite good. "But I was too shy to exhibit them. A lot of my friends were interested in drawing also, and they were much, much better than I."

**"Self Portrait" (opposite), by Vladimir Dzhanibekov.**

For the next 25 years or so, Dzhanibekov was preoccupied with the professional pursuits that led to his becoming the second most experienced space traveler in history (only U.S. astronaut John Young has flown more times). Before his selection as a cosmonaut in 1970, Dzhanibekov served as a junior officer in the Soviet Air Force for five years. Early in his space career he received a choice assignment: commander of the Soviet backup crew for the 1975



SPACE ART INTERNATIONAL

Apollo-Soyuz mission that linked American astronauts and Soviet cosmonauts in orbit for the first — and so far only — time.

Dzhanibekov's first actual spaceflight came three years later, when he and veteran cosmonaut Oleg Makarov visited another two-man crew onboard the new Salyut 6 space station for five days. Dzhanibekov returned to Salyut 6 with a Mongolian "guest cosmonaut" in 1981, and the following year commanded the joint Franco-Soviet crew that visited the next-generation Salyut 7 space station. In 1984, he joined Svetlana Savitskaya outside Salyut 7 as she became the first woman to "walk in space".

The highlight of Dzhanibekov's cosmonautical career occurred in June 1985, when he and Viktor Savinykh roared aloft from the Baikonur space center to rejuvenate the ailing Salyut 7 space station, after an electrical malfunction had drained the orbiting laboratory's batteries. The unoccupied Salyut had not been able to respond to ground commands or transmit any tracking data, but Dzhanibekov deftly located the derelict station and flew his Soyuz spacecraft to a successful docking.

For two long weeks, the cosmonauts nursed the ghost ship back to health, often working in sub-freezing temperatures that had caused ice to form inside the station. It was risky business, and the two cosmonauts worked under the most arduous conditions ever experienced by humans in space.

After his return from orbit, Dzhanibekov retired from training for space missions ("I probably won't fly anymore," he says) to devote his time to public relations on behalf of the Soviet space effort. He toured Australia in April 1986, and attended a space education conference in Boston a year later.

Although he is still an active

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**Three by Dzhanibekov: "Pre-launch" (top), "To the Stars" (above), and "Time, Forward" (opposite page). The dark horse of space facing the white horse of Earth is a recurring theme in the cosmonaut's art.**

cosmonaut, his retirement from the rigors of spaceflight training means that Dzhanibekov now has more time to indulge his passion for art. "At the moment, painting is one of my favorite pastimes," he says. "But it's more than just a hobby. It's extremely important for myself. Little by little, I've found that this is a way to discover a much deeper understanding of what I want to express."

It is this emotional factor, the urgent need for self-expression, that sets

**"My favorite subjects are space and my fellow cosmonauts," says Dzhanibekov, "but I'm more interested in portraying the connection between them and life on Earth."**

Dzhanibekov's paintings apart from the work of other space travelers who have put their visions down on canvas. He is not the first to try to capture the experience of spaceflight through art: fellow cosmonaut Aleksei Leonov and Apollo 12 astronaut Alan Bean both have achieved international recognition for their paintings depicting milestones in the Soviet and American space programs.

But Leonov, Bean and non-spacefaring artists such as Robert McCall and Andrei Sokolov (see accompanying story), often strive for a photorealist depiction of orbital vistas and space technology. In contrast, Dzhanibekov has an expressionistic style that merges light, color and subtle imagery to achieve an emotional impact.

"My favorite subjects also are space and my fellow cosmonauts," says Dzhanibekov, "but I'm more interested

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in portraying the connection between them and life on Earth."

Although he has never had the opportunity to try his hand at painting in weightlessness, he was able to produce some drawings during the Salyut 7 rescue mission. "As you can imagine, there was actually little or no time for painting or drawing," says the cosmonaut of his daring salvage, "but I was able to do some sketches — very, very few. They were of more scientific value than artistic."

From experience, Dzhanibekov has found that his first impulse about approaching an artistic subject is usually the right one, and he attempts to follow through with the original treatment until he has finished. Perhaps because he is entirely self-taught, he also is quite sensitive about having others comment on works in progress: "Whenever I show my unfinished paintings to professionals — those who really understand art — all they do is *praise* my technique, and that is something I really don't like at all."

When he does seek advice, the cosmonaut turns to those with whom he has a close personal relationship. "There's a professional sculptor in the city of Tashkent; although he's not a painter, I listen to him because he is my friend," says Dzhanibekov. "I also especially value the opinion of my wife, Lilia. Judging by her opinion, I can tell whether I've succeeded or not."

Although he has given most of his paintings to family and friends, several museums in the Soviet Union have asked to display Dzhanibekov's art. In mid-November of last year, there was a modest exhibition of his works in the city of Kaluga, the birthplace of Soviet rocket pioneer Konstantin Tsiolkovski.

Right now, Dzhanibekov is excited about a new painting — a triptych that prominently features Yuri Gagarin, the first man to orbit the Earth. Its theme, says the artist, is the meeting of two very disparate worlds — the space-age realm of high technology and the simple Russian peasantry.

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SPACE ART INTERNATIONAL

**"Windward of the Universe" (top); and "Seeds of Truth" (above), which honors Soviet rocket pioneers Friedrikh Tsander and Nikolai Kibalchich. Kibalchich was executed in 1882 for his involvement in a plot to assassinate Czar Alexander II.**

"To the left is Gagarin, just before his flight," Dzhanibekov explains. "In the center is an allegorical painting I call 'The Challenge,' whose theme will be the breakthrough of Man into space, expressed through a black horse symbolizing the vastness of space and a white horse signifying mankind." This symbolism is one of the artist's favorite images, used in several of his works.

Dzhanibekov adds that there is a story behind the third section of the triptych, entitled 'The Meeting'. Supposedly, the first two people who met Gagarin after he landed on April 12, 1961 were an old woman and her granddaughter. The old peasant woman was quite frightened by the sight of a man descending from the sky.

"That's the idea behind the painting, but the context is much more meaningful," says Dzhanibekov. "There's the whole philosophical question: what will space, cosmonauts and technology give to the simple people who live on Earth?"

Dzhanibekov estimates that he has done more than 150 pencil sketches and paintings over the years. He admires the Soviet and Russian "academic" school of art, he says, and tries to work along those same lines. But the cosmonaut-turned-artist insists that he is "trying to be myself, trying to develop my own style which can be recognized," — something that isn't easy even for professional artists.

"Ah, but the more difficult the task, the more interesting it is," says the five-time space traveler and two-time Hero of the Soviet Union. "Wouldn't you agree?"

*Les Dorr is a freelance writer in Germantown, Maryland.*

## THE DEAN OF

# SOVIET SPACE ART

PHOTO: ALEXANDER KULECHOW

SPACE ART INTERNATIONAL

**Andrei Sokolov and his recent painting of an expanded Mir space station.**

The Soviets proudly call Andrei Sokolov a *fantast* — a "visionary" — and it would be difficult to come up with a more appropriate label for the country's premiere space artist. In hundreds of paintings, his imagination has roamed from the snowy steppes of the Baikonur rocket launch site to the farthest reaches of the universe.

Sokolov has devoted his artistic life to capturing the soul of the Soviet space program on canvas. His work has appeared on commemorative stamps and postcards in the U.S.S.R., and has graced dozens of space-related publications in both East and West. One painting even hangs in the art collection of the National Air and Space Museum in Washington.

"He's inspired, dedicated — and very prolific," says American space artist Robert McCall, who has cultivated a strong friendship with Sokolov since their first meeting four years ago. "There are others in the Soviet Union who do the same thing as Andrei, but no one approaches his stature."

Sokolov originally planned a career as an architect, graduating from the Moscow Institute of Architecture in 1955. While working in that profession in the late 1950s, he was enthralled by Ray Bradbury's science-fiction masterpiece *Fahrenheit 451*, and his illustrations of scenes from the novel were his first works with a science or fantasy theme.

While most Russians were thrilled by Yuri Gagarin's single orbit of the Earth in 1961, the flight actually changed Sokolov's life. "He already had been inspired by Sputnik," recalls noted aerospace historian and space art collector Frederick C. Durant III, the artist's close friend since 1973. "It wasn't until Gagarin's flight, however, that Andrei really decided to dedicate his career to space art."

Soviet cosmonauts have a natural affinity for the subject matter of Sokolov's paintings, but they relish even more his meticulous accuracy in rendering space hardware and orbital scenery. Crews on Soviet space stations frequently assist the artist by carrying his canvases into orbit for comparison with the real thing. Sokolov's wife, Nina, even sews small pieces of velcro-like material on the canvases so they can be mounted on the station walls.

It's a measure of his "insider" status that Sokolov occasionally is allowed to solicit comments from orbiting cosmonauts via a live television hookup from the Flight Control Center outside Moscow. More often, the crewmen simply note their suggestions or corrections directly on the sketch and return the painting to Sokolov at mission's end so that he can incorporate their remarks into a finished piece.

Sokolov discovered not just an admirer, but a collaborator in Aleksei Leonov, the first man to walk in space and commander of the Soviet half of the U.S.-Soviet Apollo-Soyuz mission in 1975. Although their joint works tend to be rather conventional — "Vostok Bound for Liftoff" and "The Spacecraft Voskhod 2 above Moscow" are two of the more stimulating titles — they generate a sense of power because of Sokolov's visceral technique and intuitive eye for color and detail.

Sokolov's renditions of contemporary subjects such as the *Salyut* and *Mir* space stations (his favorites, according to Fred Durant), are done in a photorealist style that reflects his obsession with accuracy. But the artist is most dazzling when he leaves the literal portrayal of Soviet man and his machinery behind to ramble through the stars, galaxies and alien shores that no human eye has ever seen.

Now in his fifties, Sokolov may be experiencing a transitional period in his art. Bob McCall, one of seven American space artists invited to exhibit their work at a celebration of Sputnik's 30th anniversary in Moscow last October, says, "I see more subtlety in Andrei's current work. The stuff I saw on this Moscow trip had greater aesthetic qualities. Space artists in the Soviet Union are almost limited to illustration in some areas, but Sokolov, at his best, manages to transcend that."

Sokolov may well continue to produce his characteristic space art into the next century. When the first Soviet cosmonaut sets foot on Mars, it wouldn't be surprising to see him or her carefully unfold a small square of canvas in the stark Martian sunlight, then eagerly send a radio message to Earth:

"Tell Andrei it's almost as he painted it. The larger rocks, perhaps a little more ocher."

ARTWORK BY PAUL HUDSON COURTESY BALANTINE BOOKS

# Los Alamos Dreaming

*All of them work in the war factory, but some of them are looking at the stars.*

*BY ROBERT M. POWERS*

"If God lives anywhere on Earth," an Indian once told me in Albuquerque, "it must be in New Mexico." One feels there an extraordinary closeness to. . .*something*. In summer, the land flinches from the up-raised fist of the sun. Step out of the shadows into the open and the naked heat hits you like a heavyweight's jab.

Away from the great deserts are canyonlands, plenty of them, deep gouges in the ancient terrain. Imagination is not necessary. Remove the few traces of vegetation from the landscape and you *are* on Mars.

On the Pajarito Plateau, halfway between Frijoles Canyon and the Puye Cliffs, atop the eroding remains of a prehistoric volcano, lies the installation once known as "Project Y," which gave birth to Trinity and the Atomic Age: Los Alamos.

Some people call it a mesa, but it's not. It's a *potero*, a tongue of land. Had Oppenheimer not loved New Mexico, he might never have recommended "cottonwoods," which is what Los Alamos means, to the government.

But in March 1943, he and a small group of scientists took over the 54 buildings of an old boy's school to begin the Manhattan Project, or "Project Y" as it was officially known. Two hundred micrograms of plutonium arrived in a suitcase shortly thereafter.

If Tombstone was "the town too tough to die," then Los Alamos was the town too smart to die. Whatever its drawbacks as a community (it was described in 1948 as "a town of dogs, babies, and bombs, in that order") it continued. It wound up a more or less modern looking town of about 18,000 souls, one pizza parlor and a vast collection of forbidding looking buildings that house laboratories.

Along the way the merry men of Los Alamos National Laboratories (and, increasingly, women) have taken part in a march across a scientific landscape that will certainly not be repeated in their lifetimes: they have released the building blocks of the universe, tinkered with the intricate plumbing of subatomic particles, dug deeply into the structure of DNA, played games with conductivity, ordinary and super. They have messed about with the deepest furies of nature and wrapped their heads around theories that even Einstein might have found difficult to fathom.

But in all their effort, they only got close to space travel once — and that wasn't close enough. They'd like to do it again.

It isn't as if Los Alamos hasn't been involved with the exploration of space. They have from the very first. But the lab's contributions have been primarily single instruments placed aboard rockets and spacecraft, from upper atmospheric probes in the late

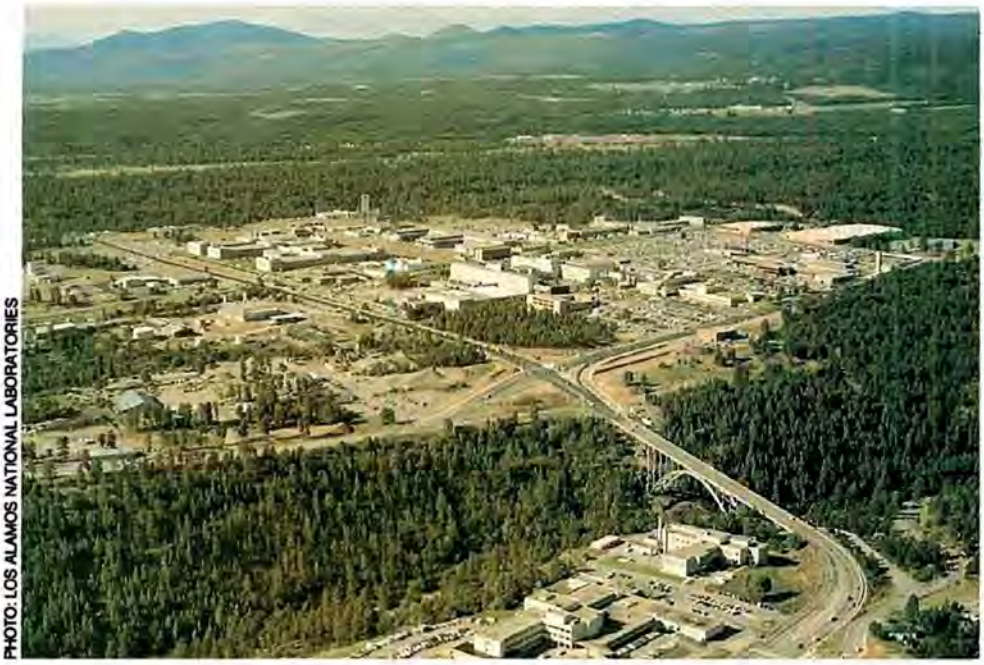


PHOTO: LOS ALAMOS NATIONAL LABORATORIES

**Los Alamos National Laboratories: "A trigger waiting to be pulled."**

1940s and early 1950s to a package placed onboard the Japanese *Ginga* X-ray astronomy satellite last year.

Manned spaceflight means lifting power: big engines, giant rockets. Los Alamos' "Rover" nuclear rocket engine program, while successful, never got off the ground. The engine had been proposed by the government when it was thought that only a nuclear propulsion system could lift the extremely heavy bomb-weight of early nuclear weapons.

When smaller, lighter bombs were developed (part of that research coming, ironically, from Los Alamos itself), the chemical rocket, which used plain old combustion to provide thrust, proved quite adequate. Cape Canaveral's manned space program evolved from modified military chemical rockets, and the Los Alamos nuclear engine was eclipsed.

In the 1930s, Wernher von Braun dreamed of space shuttles and Mars missions while at the same time working on military applications of the rocket technology he knew could make his dream come true. The men and women of Los Alamos do the same. There are plenty of interesting applications for the fancy squiggles that track across their computer screens, and those who would pursue more futuristic projects, were it not for their day-to-day defense-related work, have to deal with the "von Braun syndrome."

"A lot of people at Los Alamos are in that same boat. It's quite common," says Steve Howe, the program coordinator for Advanced Technology Development at Los Alamos. For the past ten years, Howe has been driving to get the lab involved in applying advanced technology to future space missions.

"There's always a tremendous amount of interesting research or side pursuits that you could follow — It's just that you're not funded for it. We all have to do things that I call 'programmatic,' where your main line is different from what you really want to spend your time on.

"I think that is sometimes beneficial," he continues, "because it gives you more breadth of experience to bring to the problem you really want to work on. If you spend all your time trying to get to Mars, I think you get too narrowly focused."

It is this broad experience, both theoretical and technical, that has led Los Alamos scientists and engineers to propose advanced space programs, up to and including actual hardware design. Among the areas under investigation at Los Alamos, says Howe, are "life sciences, power and propulsion, the use of extraterrestrial resources, extremely high-strength materials and structural ceramics. We have identified, internally, 38 research tasks that we felt were pertinent to advanced space missions."

It is no irony that the Los Alamos experience in nuclear matters may be one of the most important. We went to the Moon using chemical rockets. We've sent unmanned probes all over the Solar System by the same means, launched hundreds of satellites and expanded into near-Earth space.

But the chemical rocket may have overstayed its welcome. The liquid-fuel rocket has been with us since the Russian scientist Konstantin Tsiolkovsky invented it on paper in 1896 and Robert Goddard flew it in the 1930s.

Despite a hundred rocket engineers searching the periodic table of elements for the perfect combination of propellants, we have found nothing more efficient than a hydrogen-fluorine engine, and that fuel is a holy terror to handle in comparison to the more tranquil (and less powerful) liquid hydrogen/liquid oxygen engines used by NASA.

Efficient as it is in terms of the energy it produces, hydrogen/fluorine wouldn't get us to the nearest star in thousands of years, and it won't get us to Mars in much under nine months, either. The outlook for a trip to Jupiter using a chemical rocket is even more grim, with aging crew members conducting an involuntary

# DATA BASE

## Space Shuttle Launch Schedule

Space shuttle missions and their assigned cargos, through the 44th flight of the Space Transportation System. Five flights (through STS-30) are planned for the first year after launches resume, with nine flights in the second year. All payload assignments are as of December 1987, and are subject to change depending on launch schedule delays.

| FLIGHT | VEHICLE | CREW (NAMES IF ASSIGNED) | MISSION DURATION | ORBITAL ALTITUDE | PRIMARY CARGO |
|---|---|---|---|---|---|
| STS-26 | DISCOVERY | Commander: Frederick Hauck<br>Pilot: Richard Covey<br>Mission Specialists:<br>Mike Lounge<br>George Nelson<br>David Hilmers | 4 days | 160 miles | TDRS-C<br>NASA Tracking and Data Relay Satellite for communicating with spacecraft in orbit. |
| STS-27 | ATLANTIS | Commander: Robert Gibson<br>Pilot: Guy Gardner<br>Mission Specialists:<br>Richard Mullane<br>Jerry Ross<br>William Shepherd | — | — | Classified Defense Department mission |
| STS-28 | COLUMBIA | — | — | — | Classified Defense Department mission |
| STS-29 | DISCOVERY | 5 | 4 days | 160 miles | TDRS-D<br>NASA Tracking and Data Relay Satellite for communicating with spacecraft in orbit. |
| STS-30 | ATLANTIS | 5 | 4 days | 160 miles | Magellan<br>Mission to map the cloud-covered surface of Venus with a radar instrument in Venus orbit. |
| STS-31 | DISCOVERY | 5 | 5 days | 320 miles | Hubble Space Telescope<br>A permanent orbiting observatory to view the universe in visible and ultraviolet light from above the Earth's atmosphere. |
| STS-32 | COLUMBIA | 7 | 7 days | 190 miles | ASTRO-1<br>Spacelab mission carrying telescopes for ultraviolet astrophysics studies. |
| STS-33 | ATLANTIS | — | — | — | Classified Defense Department mission |

# Space Shuttle Launch Schedule

**continued**

| FLIGHT | VEHICLE | CREW (NAMES IF ASSIGNED) | MISSION DURATION | ORBITAL ALTITUDE | PRIMARY CARGO |
|---|---|---|---|---|---|
| STS-34 | DISCOVERY | 5 | 4 days | 145 miles | Galileo<br>Spacecraft for extended exploration of Jupiter and its moons. Will arrive at Jupiter in 1995 and drop a probe into the atmosphere. |
| STS-35 | COLUMBIA | 5 | 5 days | 160 miles | GPS-1 (Global Positioning Satellite)<br>Navy navigational tracking satellite.<br>IBSS (Infrared Background Signature Survey).<br>SDI experiment to test infrared sensing in space. |
| STS-36 | ATLANTIS | — | — | — | Classified Defense Department mission |
| STS-37 | COLUMBIA | 5 | 5 days | 160 miles | GPS-2 (Global Positioning Satellite)<br>Navy navigational tracking satellite.<br>SYNCOM IV-5<br>Military communication satellite |
| STS-38 | DISCOVERY | 7 | 7 days | 175 miles | Starlab<br>Spacelab flight carrying a full crew of scientists for astronomy and astrophysics studies. |
| STS-39 | ATLANTIS | — | — | — | Classified Defense Department mission |
| STS-40 | COLUMBIA | 5 | 4 days | 160 miles | Gamma Ray Observatory<br>Permanent orbiting NASA observatory to study the universe at high-energy gamma ray wavelengths. |
| STS-41 | DISCOVERY | — | — | — | Classified Defense Department mission |
| STS-42 | ATLANTIS | 5 | 4 days | 160 miles | TDRS-E<br>NASA Tracking and Data Relay Satellite for communicating with spacecraft in orbit. |
| STS-43 | COLUMBIA | 5 | 7 days | 160 miles | SKYNET-4A<br>British military communication satellite.<br>EURECA 1L<br>Retrievable satellite platform. |
| STS-44 | DISCOVERY | 5 | 4 days | 160 miles | Ulysses<br>U.S./European spacecraft to explore the polar regions of the sun. |

**"If you want to get the human race past Mars and into the middle of the asteroid belt or the moons of Jupiter, chemical systems just will not work," according to Howe.**

exercise in chemotherapy as they spent years traveling through intense radiation zones.

Los Alamos engineers are now working on a nuclear power source to supply electrical power to the space station in Earth orbit. A joint project of NASA and the Departments of Energy and Defense, the S-2100 program plan is to produce a 100-kilowatt electric plant for use in space. It does not take a great stretch of the imagination to see the same source powering an advanced base on the Moon or a scientific outpost on Mars.

A nuclear source can mean propulsion as well as power, according to Howe. If you don't care how long it takes to reach your destination, he says, nuclear electric propulsion "is an excellent option for transporting cargo or raw materials." In these rockets, a small but steady thrust produced by ions streaming out the back of an engine would build up slowly to achieve respectable velocities.

But Howe is interested in more than working up a good nuclear-electric gooney bird to trot supplies around. One concept comes directly from SDI work. "Star Wars" satellites moving from low to high Earth orbits will be very, very heavy. Weight puts a big strain on chemical rocket design. When in doubt, get a bigger hammer. Nuclear is the bigger hammer.

The Air Force is thinking about a nuclear-engined space tug to make the round-trip from low to high orbits — not simply a nuclear power plant, but an actual propulsion vehicle.

The combination of these two nuclear technologies would have a profound effect on future space missions, particularly to Mars. Los Alamos' S-2100 power source could be mated to a nuclear electric rocket to cart supplies — including fuel tanks for the return trip — to the Red Planet far in advance of the manned ship. The nuclear engine for the Air Force's space tug could be mated to a Mars Excursion Module (i.e. spaceship), and suddenly the Mars mission changes from an Apollo-like quick jaunt to a much more sophisticated expedition.

"This is the so-called 'sprint' mission," according to Howe. "You want to get the supplies there safely, and plenty of them. That means you have to lift a lot of weight. You also want the crew there *fast*. . .This additional velocity requirement translates directly into ship mass. With nuclear, you start talking about a factor of two and a half to five savings in ship mass, depending on just how fast you want to go."

In a joint Los Alamos-NASA study in 1985, the chemical mission taken as a baseline for comparison required that four million pounds of equipment be sent to low Earth orbit for a complete 60-day mission to Mars. This would use up the entire space shuttle fleet and its accessories for quite some time. The same mission with a nuclear engine package required about 1.6 million pounds to low orbit. This ship-mass difference, based on current launch costs, would save some $5-7 billion dollars in the cost of reaching Earth orbit alone.

The nuclear Mars mission would require a 90-day flight to reach the planet, a 60-day stay on the surface, and a 90-day return trip. The whole mission might be finished before an ordinary chemical rocket could get to Mars in the first place.

"If you want to get the human race past Mars and into the middle of the asteroid belt or the moons of Jupiter, chemical systems just will not work," according to Howe. The mission times are too long, and the potential physiological effects on the crew are unknown, and therefore too risky.

According to Steve Howe, the application of nuclear propulsion and nuclear power sources to advanced space programs would dramatically change the *nature* of space exploration. We wouldn't be looking at primitive Apollo-like events, but at permanent bases on the Moon, Mars, or in deep space around Jupiter.

"The key point is, we would be a bit energy-rich," says Howe. "It always seems as if NASA missions were a bit energy-poor, so they had to be extremely well thought-out. If you really want to explore space, you have to have flexibility. Nuclear gives you that. The reactors we are thinking about now [provide] direct nuclear propulsion and then convert for later shipboard electric power.

"Future space missions may not be like a lunar venture where you just hop outside and then hop right back in. You don't know what problems you'll encounter on a long stay on a planetary surface, and this power-rich aspect is one of the strong points of nuclear applications."

You also need more information, especially about Mars. Another Los Alamos scientist, Don Petit, has studied an entire "economy" for Mars, partly based on extracting oxygen from the rusty soils. A robot mission could extract, purify, condense and store large quantities of liquid oxygen or high pressure gaseous oxygen. This could be used as fuel for exploring the surface or for returning to a vehicle in Mars orbit. The experience gained during this kind of operation would later be used by a human expedition, and the robot explorer would be able to pay back some of its own costs — fuel, for example — by using the natural resources of Mars.

While the negative aspects of nuclear power are sharply etched in humanity's collective mind, it may be *the* way to go for space exploration in the 21st century. Yet, there are many scientists who think the negative image makes the idea of a nuclear engine to Mars — or anywhere else — an insurmountable obstacle.

"I've talked to a lot of people about this," says Howe, "and the way I put it is that it may not be an *American* power source. Clearly, the Soviets fly reactors in space and have a high capability in that area. Nuclear is such an obvious logical conclusion to pursue, that even if we don't, they probably will. . .or the Europeans will.

"I see space as the ideal place for


ARTWORK: MARK DOWMAN FOR EAGLE ENGINEERING

**For expeditions to the planets, nuclear-powered vehicles may be the answer.**

nuclear power to be used," he continues. "Get it out of the biosphere, up into space where we can keep it safe, keep it out of human contact and let it do its job."

If the United States started today, says Howe, with a well-funded program, we could build a flight-ready nuclear engine within about ten years. "We have an experience base, we have capabilities for doing the testing. . .we have access to the Nevada test site."

The nuclear spaceship may get us to Mars and out into the Solar System, but could it get us any closer to the stars? Perhaps not. Los Alamos, however, has a very sophisticated program that is looking into anti-matter matters.

Scientists at Los Alamos consider their "ion trap," which can store perhaps ten trillion anti-protons — exotic particles that are mirror images of normal protons — as a key technology development. When anti-matter and matter meet, so the theory goes, the mass of both particles is converted entirely to energy. If you could harness that energy in a propulsion system, the efficiencies could be fantastic.

Antimatter engines may not be as far in the distant future as has sometimes been supposed. According to Howe, "there is approximately the same amount of energy in anti-protons this year in the world as was available in enriched uranium in the mid-1930s." And we all know how quickly the folks at Los Alamos did something spectacular with enriched uranium.

"There are a couple of us at the laboratory who are trying to look into using anti-matter reaction energy transferred to a 'working fluid' — hydrogen," Howe says. "When we do that, we get figures like *three times* the best chemical fuels."

Some lab researchers also are beginning to look at so-called "plasma engines" that would produce very high-temperature exhaust for great efficiency. "You get extremely powerful engines if you could do it, but whether such engines are 30 years from now or a hundred, I can't guess."

There is nothing on the horizon, nothing even with a sound theoretical basis, that answers the basic star flight problem of how to send an enormous life-support system for a human crew across the interstellar void. Unmanned probes to another star, however, might not be that far from us in technological time.

But time takes on a different meaning in New Mexico, anyway. The past, present and future melt into a flow like the muddy water of the Rio Grande. Was it not outside Roswell, in the 105-degree desert winds beneath the blazing Sun God, that Robert Goddard struggled to test his first rocket motors in the summer of 1930? Now the space shuttle, on occasion, lands at White Sands. Astronomers near Socorro operate a gigantic radio telescope, listening for the primordial whisper that started the Universe. Physicists play with Lucifer's particles — the anti-protons.

Does it seem strange that all of this hard talking about space stations and Mars and star flight should be coming out of Los Alamos? It shouldn't. The lab is a national resource, in many ways a trigger waiting to be pulled. There are very few places that have the same breadth of scientific disciplines in a single location.

"I think those who have heard us talk about space exploration and hardware for the first time are surprised at the breadth of our capability," says Steve Howe. "And indeed, there are some people who seem reluctant to accept the role we'd like to play, people who seem a little biased against it. We're known as a weapons laboratory. Why are we talking this way?"

*Robert Powers is the author of more than 300 articles and several books on space science and astronomy. His most recent book, Mars: Our Future on the Red Planet,* was published in 1986 by Houghton Mifflin.

# MARS
## The Next Giant Leap?

*Lunar veterans Armstrong, Aldrin and Collins are just three of the voices in The Great Destination Debate.*

*BY LEONARD DAVID*

Former astronaut Michael Collins thinks we should bypass the Moon and head straight for Mars. Buzz Aldrin agrees that Mars should be the next big goal, although he says setting up a permanent lunar base could fit in the plan somewhere. And Neil Armstrong, their Apollo 11 crewmate and first man to walk on the Moon, says there isn't a clear choice: "I favor them both."

The lunar explorers are only three of the participants in The Great Destination Debate, a mostly behind-the-scenes policy discussion of what should be the next major goal of the U.S. space program. Even though everyone insists it doesn't have to be an either/or choice, the "Moon Base vs. Mars Mission" rift is alive and well in the space community.

Meanwhile, choking the upper-level in-boxes at NASA and the White House are any number of studies on the health of the nation's civilian space effort. A recent statement by NASA administrator James Fletcher is typical of the agency's recent thinking: "Now is the time to set long-range goals in space — goals of vision and purpose — and commit ourselves to attaining them."

Still tormented by the Challenger catastrophe, NASA finds itself today on a soul-searching binge. The international space station — the agency's next big project — has become entangled in budgetary bickering and debate over its primary purpose and overall utility. Clearly, NASA is not the same group that shot for the Moon and made it. As one NASA insider recently commented: "You know we're in trouble when we have day-long meetings on the difference between 'leadership and preeminence.'"

In the 1960s, the momentum of Apollo was expected to carry over to constructing a permanent base on the Moon and rocketing onward to the distant dunes of Mars. But "Moonwalking" was a lost art by the early 1970s, a victim of shifting economic priorities, the war in Vietnam and a faded love affair between taxpayers and faraway astronauts. With the curtailment of the Apollo program, so went NASA's dreams of setting up lunar outposts and dispatching astronauts to the red planet.

ARTWORK: PAUL HUDSON FOR ORBITAL SCIENCES CORP.

But momentum is once again building within the space agency to articulate a bold new goal. Considering the ports-of-call suitable for expeditionary crews, you don't need a degree in planetary science to reason out a road map. Obviously, setting up sauna baths on Mercury seems frivolous; so, too, is bounding across the hellish terrain of Venus. Mars and the Moon remain the only two viable candidates in the inner Solar System for human exploration.

For many in the NASA community, the destination debate is not so much a question of "Moon versus Mars" as it is coming to grips with a central problem: How to sustain political and financial support for civilian space activities.

Some long-term thinkers fear that a goal-minded NASA would simply sprint to Mars, grab some red rocks, plant a flag, salute and return to Earth. This one-stop-shopping scenario, argue the critics, would be an end run around a more evolutionary approach to the human exploration of space. Better to systematically reap the benefits from commercial enterprises such as mining the Moon, they say, and then move out permanently into the rest of the inner Solar System.

PHOTO: NASA

**Apollo was a proud achievement, but it left only abandoned hardware and footprints on the moon. A lunar base would be our first permanent outpost on another world.**

Others yawn at the prospect of the United States being the first country to return to the Moon. If we did it once, they say, why do it again?

Supporters of a lunar base initiative caution that the country cannot afford an expensive replay of Apollo. In this camp is none other than America's first woman in orbit, Sally Ride. Prior to her departure last year from NASA, Ride headed a task force on the future direction of the U.S. space program. Her report warned that the next goal for human space activity should "not be another Apollo — a one-shot foray or a political stunt."

The Ride study group favored the construction of an outpost on the Moon as a site for the "natural progression of human exploration" before going to Mars. In the Ride scenario, humans would return to the Moon in the year 2000. Five years later, there would be a lunar outpost capable of housing five astronauts for several weeks at a time. By 2010, a group of 30 explorers could be living on the Moon for months at a time.

"It is not absolutely necessary to establish this stepping stone, but it certainly makes sense to gain experience, expertise, and confidence nearer Earth first, and then to set out for Mars," the report concludes. The point is well taken; a Mars journey would be equal in duration to 150 Apollo voyages.

Moon-first advocates argue that the necessary fuel for a Mars mission could be produced in lunar processing plants that would turn rocks into liquid oxygen. Exciting science and astronomy projects could be carried out there. And occupying the Moon on a permanent basis would stimulate space enterprise, resulting in a host of profit-making ventures.

**National Commission on Space Chairman Thomas Paine: "I have strong feelings that the Moon versus Mars is a phony issue. The inner Solar System is our real destination."**

The "Martians," however, have a different point of view. "A lunar base wouldn't be a detour on the road to Mars, but a trap. We would use up [financial] resources and indefinitely delay going to Mars," said Cornell astronomer Carl Sagan at the third "Case for Mars" conference in Boulder, Colorado last summer.

"Mars is so much more exciting," continued the popular cosmic communicator. "It has so much more romance than the Moon. It's a much more feasible goal."

Sagan is also president of the California-based citizens' group, The Planetary Society. Beginning last year, the society embarked on what it calls the "Mars Declaration" campaign. Among other benefits, the document says that human exploration of Mars would be a stimulant for U.S./Soviet cooperation, not only in space but here on Earth. A Mars goal is also "a step toward the long-term objective of establishing humanity as a multi-planet species," states the declaration.

Signers of the document include such notables as Jimmy Carter, former U.N. ambassador Jeane Kirkpatrick, several former NASA administrators and ex-astronauts, Nobel prize winner Linus Pauling,

columnist Jack Anderson and television personality Hugh Downs. The list is growing rapidly. One of the society's objectives is to transform into political action what it believes is a strong clamor for Mars, with an eye toward the new group of space policy makers to be in power by 1989.

"I'm surprised and gratified at the breadth of support the Declaration is receiving" says Louis Friedman, the Planetary Society's executive director. Emphasizing that there is no need for a "Moon versus Mars" controversy, Friedman notes that "there are only a few weirdos in the space community who think because we are advocating a human mission to Mars that we're against all the steps to get there.

"I'm terribly impressed by the fact that all these astronauts who have been to the Moon are for the Mars goal," says Friedman. "They understand, perhaps better than any of us, that humankind reaching outward is an exploratory goal. None of these people argue,'Let's go back to the Moon and do it right instead of going to Mars'."

In fact, the Apollo 11 crew have all joined the ranks supporting the Mars Declaration, although each offers a caveat. Particularly clear about declaring Mars as a goal is Michael Collins, who circled the Moon in 1969 while his colleagues strutted across the surface. Collins takes the go-directly-to-Mars-and-don't-collect-dust-on-the-Moon approach.

"I think we should set our sights on Mars and make that the goal," believes Collins. "When we start the Mars planning in detail, I think it will become apparent whether you need to go to the Moon as an intermediate step or not. I don't think a colony on the Moon helps with Mars. It just diverts attention and funds...and slows down the process. It may even cause both goals to get defeated politically, because I don't think the Moon is that attractive a place."

Collins, a Washington-based aerospace industry consultant and a popular writer on space issues, suggests that choosing humans-on-Mars as our prime objective would also clarify the purpose of NASA's planned space station, which would then be designed as a base in Earth orbit for constructing Mars vehicles. "Right now, a criticism is that no one knows what that space station is supposed to do," he admits. "To oversimplify, if you were to rename NASA the National Aeronautics and Mars Administration, the purpose of the space station will immediately become clear and it would end the squabbling."

Giving a hesitant thumbs-up on a Mars goal is Neil Armstrong, long retired from the astronaut corps and now a businessman in Ohio. His last major involvement with the space program was as Vice Chairman of the President's Challenger accident commission in 1986. The somewhat reclusive Armstrong offers (due in large part to having nearly every television camera and microphone in the world thrust in his face after his return from the Moon) a guarded view on a Mars commitment. Rather than choosing between destinations, he sees the development of new space transportation systems, life support equipment and propulsion technology as the key ingredients for placing humans anywhere in the Solar System.

"I'm a firm supporter of a strong technology development program," he says. "It's perhaps the highest yield investment that the government can make."

Armstrong's fellow moonwalker, Buzz Aldrin, is now a lecturer and consultant living in California. Aldrin believes the Soviet Union may well beat an early path not only to Mars, but to Venus as well. "I think the Soviets will take advantage of a manned flyby of Venus and back to Earth, followed by a manned flyby of Mars at the earliest opportunity, probably by the year 2000. What that leads to afterwards, I don't know."

Like Collins, Aldrin proposes that the "declared destination" in the future should be Mars, with a program that makes maximum use of the Moon enroute to Mars. "What that means, in terms of the Moon, I don't think you can say right now," he adds. "I don't think the nation should be asked to buy a return to the Moon, permanent,

*continued on page 62*

PHOTO: NASA

PHOTO: THE WHITE HOUSE

**Apollo 11 astronauts Neil Armstrong, Michael Collins and Buzz Aldrin in 1969 (top, L. to R.), and at a White House ceremony in 1984. All three have endorsed the "Declaration of Mars."**

# THE LONELIEST PLACE ON EARTH

*If space is anything like Antarctica, long-term astronauts will face the dreaded Big Eye and Long Eye.*

*BY RAY SPANGENBURG AND DIANE MOSER*

Even for astronauts it would be no easy world. A challenge to the human eye and imagination, the five million square miles of icy desert stretch out into unceasing loneliness, mocking the very idea of unaided human survival. The harsh glare of a yellow sun burns unendingly at summer's height, erasing — seemingly forever — the night.

Then, in a gradual reversal, a constant darkness drops over the landscape, bringing temperatures as low as -117F and a vanishing sense of time itself. Winds up to 101 knots knife through the darkness — freezing, deadly and unforgiving of error. The world collapses inward, and minds and emotions struggle against a claustrophobic night that lasts for months.

An expedition to some alien planet? Almost. The scene: the continent of Antarctica — perhaps the closest analogy on Earth to the conditions astronauts might face in space. For the combined isolation, danger, sense of confinement and loss of privacy, many psychologists are looking to Antarctica as a model of life on a space station or a Moon base. The Antarctic also can serve, the psychologists believe, as a training ground for understanding human dynamics in the cramped quarters of a future spacecraft bound for Mars.

An expedition to Mars, given today's technology, would take nearly three years — two there and back, plus one year on the planet. How will human beings react to living in the harsh and alien Martian environment, tethered by only the most fragile umbilical cord to their home more than 35 million miles away? We have little knowledge of the psychological factors that might come into play over such a long journey. The U.S. space endurance record, held by the Skylab 4 crew, is only 84 days, while Soviet cosmonauts have yet to eclipse the one-year mark onboard their Mir space station. Of his own experience on Skylab 2, former astronaut Joseph Kerwin says, "Twenty-eight days isn't really very long."

The typical stay in Antarctica, lasting up to 18 months, exceeds our current experience of isolation in space. Antarctic models exist for small spacecraft crews as well as planetary bases; research communities range in size from four people at smaller stations, up to 100 or as many as 1000 people in the summer at larger stations. The mix of men and women with construction, scientific, engineering and support backgrounds — and the potential for international cooperation — all add up to social dynamics in Antarctica that might also apply to long-duration space missions.

Kerwin, who was the first American medical doctor in space, says "I think that the psychological problems...that we may have to deal with or prevent on the space station aren't linked to weightlessness. They will be qualitatively the same kind of problems that isolated, confined people get in Antarctica or in submarines." Further, he adds, "I think that NASA should pay considerable attention to the experiences of people in Antarctica."

In fact, official interest in the analogy is picking up. The National Science

Foundation, which oversees all U.S. activities on the southern continent, joined NASA last summer to co-sponsor a conference examining applications of the antarctic experience to life in space. Whether this will translate into on-the-spot psychological research (little has been done in the 33 years of U.S. presence in Antarctica) remains to be seen. But Al Harrison, a University of California at Davis psychologist who has been working with the Space Human Factors Office at NASA's Ames Research Center, antarctic specialists like Navy Health Research Center anthropologist Lawrence A. Palinkas and veterans of the ice all agree: It should.

"Not only for the sake of future astronauts," points out NASA/Ames planetary scientist Chris McKay, "but also just to improve the quality of life for those of us who go down there. It just makes common sense."

McMurdo Station, the largest American base in Antarctica, may host as many as 800 to 1000 people during the short antarctic summer, when scientists with military and civilian support crews bustle in to do what one ice veteran termed "one year's work in three months."

Most of the summer work draws to a close by the end of January, when ships and planes ferry the visitors home. By the end of February, only 90 or so remain at McMurdo — with 24 other Americans divided among the South Pole, Palmer and Siple Stations — to brave the Antarctic winter.

"When that last plane leaves, you know that's it — there's no turning back," says Steve Lasley, an oceanography student who wintered "on the ice" in 1977-78.

Treacherous antarctic storms and the 300- to 1000-mile belt of sea ice surrounding the continent make both air and sea travel out of the question during the winter. "They don't really make emergency evacuations," concurs psychologist Donna Oliver, one of the first women to spend a winter at McMurdo.

Cut off from incoming supplies and outside communication, a moment's mistake can mean death. Where the wind chill factor drops to -165F, a turn into the wind can freeze eyelids closed. A vehicle driven off the road can result in disaster. Forgetting to put on your gloves can leave your fingers so numb and frozen that in a matter of seconds you can't make them move — can't open a truck door or zip up a parka. Like an alien planet, the Antarctic can eat you alive.

But, severe as it is, the weather may not be the biggest enemy. Like future Mars voyagers, those who winter over on the ice face months of isolation, thousands of miles from family and friends. They are cut off from the world as we know it — TV, radio, CNN news, newspapers, magazines, commercials, Big Macs, barking dogs, rustling leaves and honking taxicabs. During thirteen months on the ice, Steve Lasley says, the only plant life he saw was a little lichen clinging to a rock.

Confined with a relatively small group of people, Oliver says, you soon find that you've heard everyone's war stories, know the punch lines to everyone's jokes. Everything is the

**Like an alien planet, the Antarctic can eat you alive.**

PHOTOS BELOW AND ON PREVIOUS PAGE: DALE ANDERSEN FOR THE NASA EXOBIOLOGY PROGRAM.

same every day — the place, the people, the food, the routine.

"The only thing that happened that I can remember in the month of May," says Lasley, "is that the Air Force flew a plane down at very high altitude on some sort of navigation training. We all raced outside and jumped up and down and yelled at the airplane." Aside from that, he says, "I can't think of anything else that happened in that month."

Although winter-over candidates must pass psychological and psychiatric screening, during their stay most people experience forms of mild paranoia, depression, "driftiness," sleep loss, mental numbness, social withdrawal, intense loneliness, anxiety and lethargy.

Safe back home, veterans of the ice laugh at the forgetfulness and spaced-out stares they saw all around them and experienced themselves. But the implications of danger and diminished capacity are obvious for the Antarctic and space environments.

"It's like your mental organization goes to pieces," Lasley explains. "I think what happens to you is both a sensory and emotional deprivation. You tend to internalize everything...You're responsible to someone, but your boss is thousands of miles away, and there's no one to respond to. You're not on your feet mentally."

As Harrison sums it up, "It's a senility-type syndrome." And recovery can take anywhere from two months to two years after returning.

This cognitive disorientation is perhaps the most critical manifestation of a long series of symptoms, and so little study has been done that its exact causes, and even its effects, aren't fully known. Oliver tells about one man who just walked off into the snow and was never heard from again. No one knows why — was it because of disorientation? Or depression? Was it suicide, or an accident?

Of course, no one expects for all astronauts to have such extreme or dramatic problems. "The real concern that we have," says NASA socio-technologist B.J. Bluth, "is human error, mistakes." When people are stressed, they make mistakes or collect data incorrectly. They take longer to do their work, misunderstand, don't hear or see

important signals in their environment. In an isolated, confined situation like the Antarctic or a spacecraft, the environment acts as a catalyst that accelerates and intensifies the negative effects of stress.

Interference with sleep, too, is a common complaint in Antarctica, says Harrison — to the extent that sufferers are said to have a malady called "Big Eye."

"Someone might take a napkin at dinner in the mess hall, wad it up in a ball and stuff it in his eye — Big Eye, right? We would all break up laughing," grins Oliver as she demonstrates with a restaurant napkin, admitting that humor there runs to the bizarre. The name refers not to napkins, but to deep circles under the eyes from lack of sleep. The cause isn't clear. Is Big Eye due to the long antarctic night's interference with the body's circadian rhythms? Or the pots of coffee consumed — Oliver estimates 18 to 25 cups could be typical — in a futile attempt to snap out of the mental numbness? Or is it related instead to bouts of alcohol consumption, loneliness and depression?

Then there's Long Eye, a form of social withdrawal characterized by Palinkas as "the 12-foot stare in the 10-foot room." It may be linked to the rigors of fitting in socially with a group you can't walk away from, and whose members can't walk away from you. "The fear of social rejection," says Harrison, "is a big threat in these environments because you don't have a support network. If you get people down on you — or you think people are down on you, it can be devastating."

As Lasley sums it up, on the ice "somewhere in the middle of the winter you really come face-to-face with yourself." Not everyone likes what they see.

We already know that depression on the ice has its corollary in space. In 1985, the Soviet Soyuz T-14 crew cut short its stay aboard the Salyut 7 space station after two months because, according to reports, Commander Vladimir Vasyutin had developed a severe case of depression. A case so serious, apparently, that by the time they reached home, Vasyutin was no longer commander of the craft.

PHOTO: DALE ANDERSEN FOR THE NASA EXOBIOLOGY PROGRAM.

**Scientists and other personnel bound for Antarctica endure a seven hour flight from Christchurch, New Zealand before their transport plane lands on the sea ice at McMurdo Station. Once "on the ice," visitors are greeted by otherworldly landscapes like the Wright Valley's "Labyrinth" (opposite page).**

But the news from Antarctica is not all negative. Winter- over veterans tend to look back on their experience — much as astronauts do — with a certain pride in a difficulty overcome. There may even be positive effects on health. Palinkas has examined hospitalization records for returned Navy personnel who had wintered over in Antarctica between 1963-1974. He found that they appeared to be significantly healthier than his control group of men who had also been accepted for Antarctic duty, but who hadn't gone for one reason or another. Palinkas thinks it's possible that unknown factors in this stressful experience produce positive coping skills and a sense of uniqueness and accomplishment that make veterans of the ice healthier in the long run. If he's right, those factors might also come into play aboard the space station or a Mars Mission.

Of course, the Antarctic/space mission analogy isn't perfect. When winter sets in on the ice, storms often cut off even radio communications to the outside world. A Mars crew might suffer this kind of isolation, but on all space missions so far, astronauts talk constantly with ground support teams. ("They were on our backs all the time — every time we passed over a ground station," remembers Skylab astronaut Kerwin) and on the space station that's likely to continue. Space-station crews also will enjoy the benefits — and face the initial discomforts — of weightlessness. On Antarctica, and on Mars, gravity remains part of daily life. In Antarctica, you're stuck — you can't come home even in an emergency. Here again, the Antarctic experience would be more analogous to a Mars Mission than to the space station or a lunar base.

On the other hand, in Antarctica, you can go outside almost any time you want to. On a spacecraft, you can't go for a walk to stretch your legs or take in the fresh morning air. You can't get away from the people you're working and living with, even for a short break out under the stars. For this aspect of space travel, a nuclear submarine or a marine research vehicle provides a better analog.

Psychologists already can offer several suggestions to ease the tension and the dangers caused by decreased alertness. Both Oliver and Harrison promote the idea of a buddy system to offset psychological and social problems. "You need someone," Oliver says, "with whom you can discuss problems and work out logical, practical solutions that will work." In space this isn't likely to translate to weekly counseling sessions between astronauts. Rather, each person would make a

**On the ice, "somewhere in the middle of the winter you really come face-to-face with yourself." Not everyone likes what they see.**

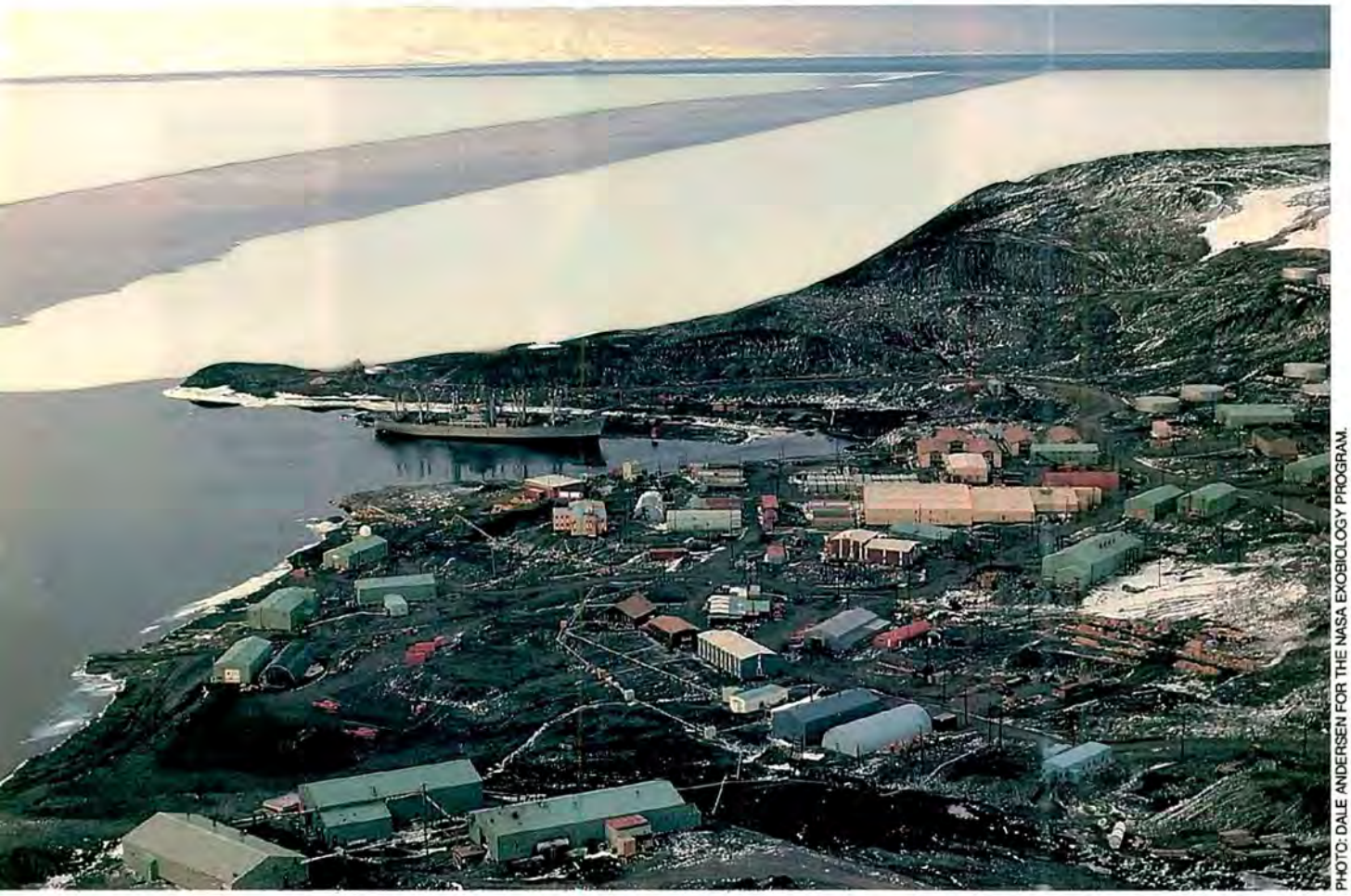


PHOTO: DALE ANDERSEN FOR THE NASA EXOBIOLOGY PROGRAM.

commitment to one other person on the team to be "a kind of special friend," says Harrison, "that helps you out when the going gets rough and snaps you out of it" when you begin to drift, or when you're angry at someone's smart remark.

Harrison also envisions training sessions prior to departure — whether for Antarctica or for Mars — to teach people how to recognize psychological and social needs. Veteran astronaut Tony England agrees that a pre-launch training program would be useful, particularly for the space station, where international crews with different cultural backgrounds will need to work together smoothly. While a long mission will always include some friction, he says, it's a lot better to work out the conflicts before you go. "If you don't do that," England says, "on a long mission it can get very nasty.

Where issues of community and privacy are concerned, the environment can play a key role. "When I first went to Antarctica," says McKay, "they had a movie theater — with popcorn and everything. It was great. The next year I went back and I couldn't believe it — it was gone." Video technology had come to McMurdo — but the opportunity to go somewhere, to go out to the movies, had disappeared, and with it both a major entertainment distraction and an important connection with home.

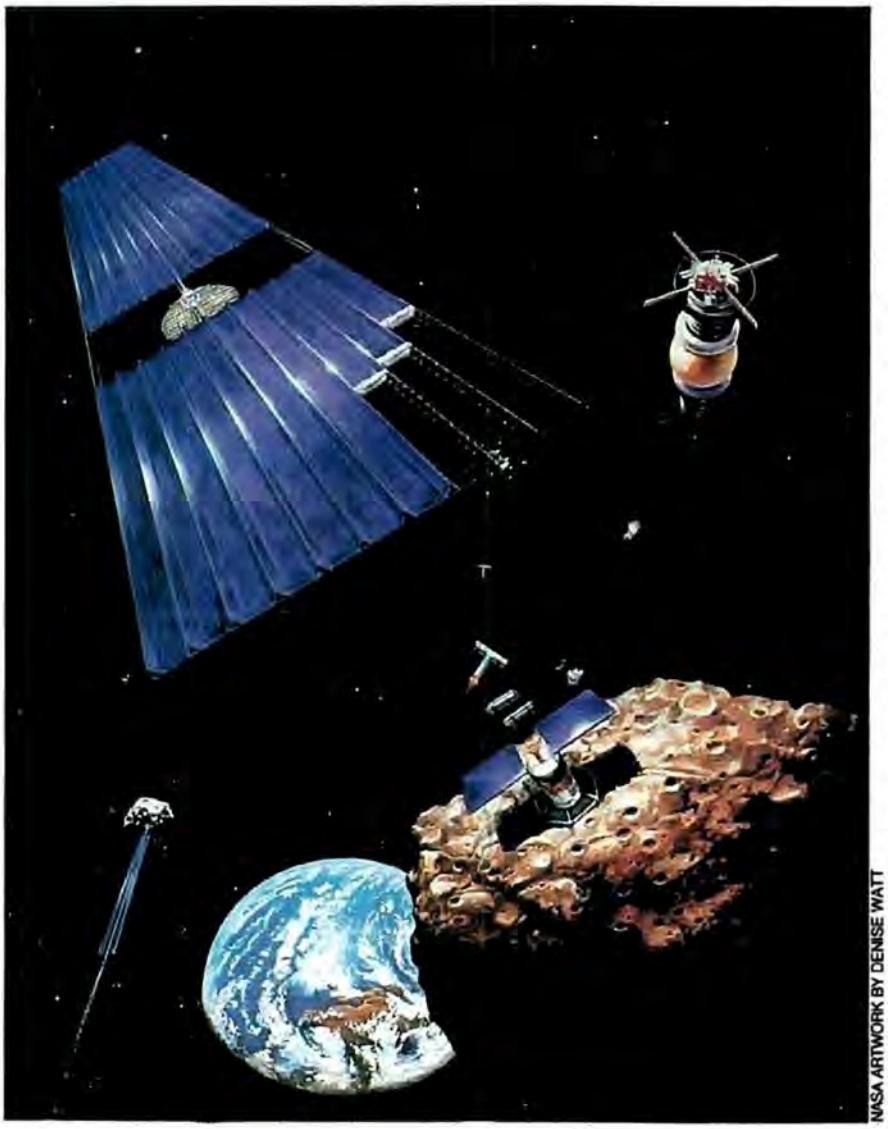
Ideally, Harrison says, people should have places where they can be completely by themselves, as well as a place for private small-group or individual conversations, and larger environments where interaction is promoted

For those working on designing the insides of spacecraft or planetary bases, the ultimate goal is to provide a place, a "womb," that promotes good work and creativity — a homestead on a new frontier. The need for that is critical. Sending people into space takes advantage of the uniquely human ability to deal with problems in inventive ways and handle unexpected phenomena. But what if those minds have become numbed by boredom, or confused by social and psychological tensions? What if the humans have become little more than robots — and worse, robots subject to forgetfulness, anxiety, paranoia and all-too-human error?

*Interview:*

# GERARD O'NEILL

THE FATHER OF SPACE COLONIES STILL KEEPS THE FAITH.



NASA ARTWORK BY DENISE WATT

**The future according to O'Neill includes orbiting solar power satellites (above, upper left) built and operated by workers living in large space habitats (upper right). In the foreground, an asteroid is delivered to Earth orbit to be used for raw materials.**

PHOTO: TOM KELLY

**Gerard O'Neill**

In a sense, Gerard O'Neill picked up where the astronauts left off. When he wrote his first article about space colonies in 1974, the last Apollo expedition had only recently returned from the Moon, leaving the open question of what would be our next great adventure in space.

Into that "dream gap" stepped O'Neill. Then a 45-year old physics professor at Princeton, he already had invented the standard technique for storing subatomic particles in a collider.

O'Neill's interest in space colonies began when he posed a question to his freshman physics class in 1969: "Is a planetary surface the right place for an expanding technological civilization?"

Their surprising answer was no, and from that seed grew the modern concept of an artificial colony in space, where thousands of people would live and work in a self-contained mini-world.

Others had written about space colonies before O'Neill, but he added the technical details, including methods for creating artificial gravity inside a turning cylinder, and even the economics that would justify a massive exodus into space.

In his book *The High Frontier*, published in 1977, O'Neill outlined the future colonization of space. Inside slowly rotating spheres stationed at libration points (where the Moon's gravity balances the Earth's), colonists would live and work in environments that were artificially heated, powered and lit by the Sun. These first "Island One" colonies were modest in comparison to the proposed growth-version. "Island Three" colonies would have ten million people, along with villages, apartment complexes, forests, lakes and farmlands, all lining the inside of a 15 mile-diameter sphere with a total acreage half as large as Switzerland.

The building materials would come from the Moon, where "mass drivers" — magnetic catapults — would lift material from the low-gravity lunar surface into space. Space colonists

Can we justify the cost and danger?

If the antarctic experience is any indicator, we need to find antidotes for the disorientation, loneliness and for Big Eye and Long Eye, before we take off for Mars. The cry among psychologists is for more research in parallel settings such as Antarctica, undersea research vehicles and nuclear submarines, so that they can at least begin to work out the details of a kind of controlled human ecology.

The long, cold night of Antarctica may be the way to discover the bright new day of Mars — and the psychologists are starting to take a closer look.

*Ray Spangenburg and Diane Moser are West Coast writers who specialize in space science and technology.*

## *Mars on Earth*

Because Antarctica's cold, dry climate provides an excellent, if not perfect, model for the physical environment of ancient Mars, Chris McKay of NASA's Ames Research Center and fellow planetary scientists Steve Squyres of Cornell University and Susan Nedell of Washington University are taking a close look Down Under.

The object of much of their investigation — a perpetually frozen lake in one of the continent's dry desert valleys — may hold clues to what life was like, if it existed, billions of years ago on the surface of Mars. Over a period of six antarctic summers McKay has been diving through the 10-foot layer of ice capping Lake Hoare, worming his way through a manhole-sized opening, to crack the mysteries of the water below. He and his colleagues have been looking at the properties of the lake water, the characteristics of the green algae that live there and the sediment that collects in dome-like deposits on the lake bottom.

Their work may have exciting implications for theories about life on Mars. Through her study of Mariner 6 and 7 photos taken during unmanned flyby missions in 1969, Nedell has spotted some areas in the Valles

Marineris (Mariner Valley) where the sedimentation looks like it was caused by standing water sometime in the planet's past. Given the big chill Mars has endured throughout much of its history, any bodies of water were probably perpetually frozen over, much like Lake Hoare. Could life have developed there, long before the water disappeared from the surface of Mars?

The presence of green algae in Lake Hoare, and the evidence of supersaturated gases caught beneath the frozen cover, may mean that the answer to that question is yes. Despite the thin atmosphere and dry surface, the Martian environment, like Lake Hoare, might once have provided a combination of sunlight, water and dissolved carbon dioxide for primitive life forms to develop in.

So at six-to-eight week stints, during the short antarctic summer, these scientists and their colleagues dive into the icy waters to take core samples, check instrument sensors left during previous dives and survey the algae and the bottom topography.

**McMurdo Station, Antarctica's largest "town," (opposite page) sees a population boom each summer, when up to 1000 visiting scientists descend on the frozen continent. At left, NASA researchers and other investigators drill holes in the thick ice capping Antarctic lakes to study underwater microbial "mat" colonies (below), which may provide clues for finding fossils on Mars (below left).**

PHOTO TOP LEFT AND BELOW BY DALE ANDERSEN FOR THE NASA EXOBIOLOGY PROGRAM; BELOW LEFT, NASA.

"I didn't find it claustrophobic," McKay remarks. "The biggest problem is that once you're down in the lake you can't see the hole any more. You can't see where to get out." So divers carry a line down with them that they can follow back when it's time to come out. The work is arduous and cold, but the results are paying off.

McKay thinks Antarctica's "scientific frontier community," where visiting researchers study everything from seals to the ozone layer, holds lessons for the human presence in space — including the achievement of both scientific and political goals at the same time. Another lesson may be in how to run a science program where the cost of operations is high. According to Tony England, who has experienced both spaceflight (as an astronaut aboard Spacelab 2) and the Antarctic (as a geophysicist for the U.S. Geological Survey), "The cost of operating down there is so large that there's the possibility it may dominate the science objectives." Operating costs may run $50 million a year, with science running only $5 million.

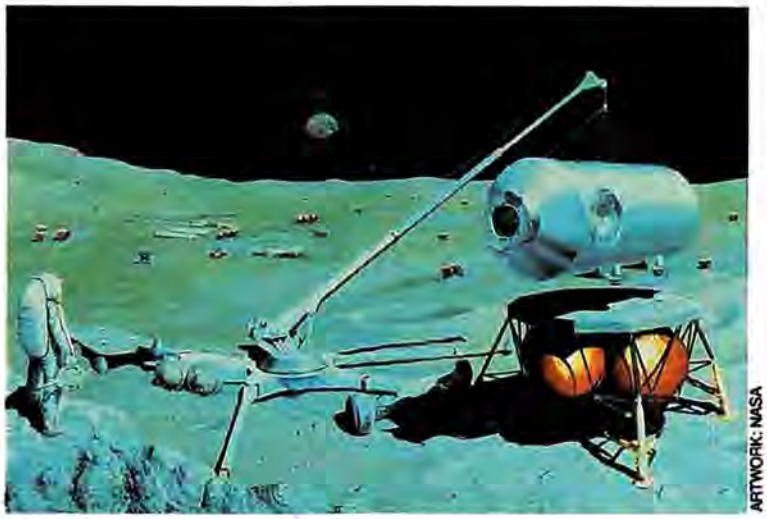
The National Science Foundation, England says, has worked it out admirably: "Where safety is involved, or efficiency is involved, operations have to take the lead. Where the objectives are involved, then the science takes the lead. So it is done in a very balanced way. I was impressed."

would work building and maintaining solar power satellites — huge orbiting arrays that would convert free energy from the Sun into microwave beams for generating clean power on Earth.

Rather than dismissing it as fantasy, the official establishment gave the idea serious attention. NASA and the Department of Energy conducted studies to look into the feasibility of space colonization, and O'Neill was even invited to testify before Congress. But by the end of the 1970s, the government had lost interest in a solar power satellite technology it saw as too expensive. Despite occasional hints of Soviet and Japanese interest, little substantial work has been done since then on solar power satellites, and space colonies remain just a dream.

In the meantime, Gerard O'Neill became Professor Emeritus at Princeton. He founded the Space Studies Institute there to conduct research in space industrialization, started a company to bring satellite position-finding technology to the small-scale user, and was a key contributor to the 1986 National Commission on Space report on future activities in space.

I visited Dr. O'Neill at his home in Princeton late one afternoon toward the end of October. Bridging his house and office is a kind of greenhouse atrium, with tropical plants and louvers that control the availability of sunlight — similar to what he has proposed for space colonies. I frankly expected O'Neill to have lost some of his enthusiasm for the ideas he had proposed more than a decade earlier. I found just the opposite. — Tony Reichhardt



ARTWORK: NASA

**Mining operations on the Moon would supply oxygen, silicon, aluminum and other resources for a developing space industry.**

**Final Frontier:** A few years ago, in your book *2081*, you wrote that "Well before 2081 a substantial fraction of the human population may be living in space colonies." Do you still believe that is possible?

**Gerard O'Neill:** Oh, very much so. I would say that the happenings of the past seven years reinforce that view very strongly. I think it was a conservative statement when I made it and I feel now even more so. I feel virtually certain that it will be true.

**Final Frontier:** Let's go back then to a more daring prediction from *The High Frontier*, where you wrote about "Island One" type colonies in the 1990's.

**O'Neill:** It's really a question of when the decision is made. The context of the original statement was that from the moment of decision that we are going to build a space colony of that kind to the time when it is built would be under ten years. And I still believe that to be the case.

One analog, of course, is the Apollo project, which was done in just eight years. Some of the big hydroelectric projects built in recent years, generally speaking, have been done within a decade. Under wartime conditions, the enormously more sophisticated Manhattan Project took place within a period of a little over three years. It was an incredible accomplishment at the time, and far more sophisticated, scientifically, than anything we are discussing here.

**Final Frontier:** If you were to rewrite *The High Frontier* now, what changes would you make?

**O'Neill:** Interestingly, we've looked at that question just within the past few months, because there is a new edition being brought out in 1988. I've made the decision without anybody feeling — at least so far — that it's a rotten idea, that the whole main text be left completely unchanged. We're not going to change a single word in it. There will be a new preface and a new additional chapter at the end of the book, but there really isn't anything that I feel we have to undo. *The High Frontier* was written from the premise that the optimum geometry for a space colony was a sphere, and that remains true today. The problems of fundamental geometry for a space colony design, I think, were really pretty well wrapped up by about ten years ago. There has been a lot of progress on what you might call the "here to there" intermediate steps. Several specific technical devices have made much more rapid progress than we had expected.

**Final Frontier:** Such as?

**O'Neill:** The mass driver is the obvious example. The best mass driver that we had operating at the

**"The space colony is a piece of real estate that can be moved virtually anywhere in the Solar System within about one generation. That's a really new thing in human existence."**

time *The High Frontier* was written was able to do about 35 gravities of acceleration. By 1983 we already had a mass driver running with an acceleration of 1,800 gravities and that's already so high that there really isn't any particular purpose in pushing any higher.

**Final Frontier:** Let me switch gears. Why do you think this idea caught everyone's imagination in the 1970s? You weren't the first person to write about colonies in space. Why did it become popular when it did?

ARTWORK: NASA

**An "Island One" colony as envisioned in 1977: Utopia on the inside of a sphere.**

**O'Neill:** I think, first of all, that the timing was right, in that the space program was old enough that people accepted it as a reality. The Apollo project had relatively recently been completed and was, of course, an enormous success. So people realized you could in fact put people out in space and they could be brought back safely. That was in the realm of science fiction as little as twenty years before.

I would say there were two other important reasons. One was that previous ideas about space colonies had been very conceptual and hadn't gone into nuts-and-bolts detail and figured out how the heck you really do something from an engineering viewpoint. In the four or five years of research that I did part-time that led up to the earliest articles and then to *The High Frontier*, I really did go into every branch of science that seemed to be relevant, including agriculture, and really made sure that the numbers were right and that there were answers for all the technical questions that could be raised. It's not that it took any great talent to do that. Anyone could have done that twenty, thirty, forty years before, but nobody did. Nobody had the combination of interest and desire and the precondition of an existing and successful space program.

**Final Frontier:** Your ideas also came at a time when concern with the energy crisis, the population boom and environmentalism were at their peak. Now they're no longer hot issues, and some of the interest in space colonies has died down.

**O'Neill:** I think the long term problems are still with us. The thing that I reacted very violently against [in the 1970s] was the "limits to growth" conclusion that we had to give up the development of western human society toward greater individual freedoms and freedom of choice. That was anathema to me, and still is. What is certainly true is that the Earth and its population will need to use an enormously greater quantity of energy than is used today, if you accept that the mass of the world's population must go through the industrial transition to escape poverty and starvation.

**Final Frontier:** I think a lot of people have been uncomfortable with the utopian nature of your ideas. In *The High Frontier*, you explicitly said "This is not a Utopia," but it sure seems like one. It's a perfect world in a sphere, and one normally doesn't associate comfort and harmony with frontiers.

**O'Neill:** Although, I took care to point out that as long as people are there, it's not going to be a perfect world. People who are unhappy on the Earth aren't going to be made happy by going out and living in a space colony.

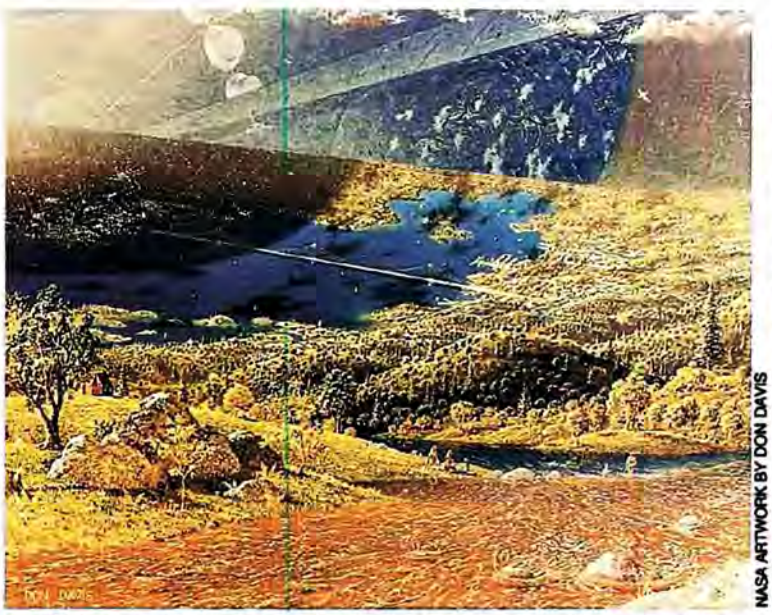
**Final Frontier:** But that wasn't the image in the book. It's a glowing vision.

**O'Neill:** Well, I hope so, and I don't make any apologies for that. I don't think I need to. There are physical requirements for a satisfactory human condition, as well as social and political requirements. One purpose for designing space colonies was to solve in an environmentally clean and acceptable fashion the problems of a modern high-technology society. In the case of space colonies it will be solved by designing a system which runs completely on solar energy and does not burden the Earth with pollution — a society in which energy would be so cheap that everything could be recycled. Materials would be relatively more expensive than they are on Earth, which also favors recycling. So on the one hand we have a technological solution to a

**"I think logic and reality will soon enough teach people who are working out in space that it makes more sense to be living in space colonies than on the surfaces of remote and hostile planets."**

specific problem: How do you make a high energy-using, therefore technically very free, human civilization?

The second part of space colony design is a curious interaction of sociology and politics. The natural size of a space colony is in the range of from 10,000 to 50,000 people, and it would be highly moveable. It's a piece of real estate that can be moved virtually anywhere in the Solar System within about one generation. That's a really new thing in human existence. Our territories here on Earth are anchored down. You cannot move them. That's one of the many reasons we have been in so many wars, because of that anchored down territory. I think scale is important also. Our experience is that when societies go beyond the scale of 10,000 to 50,000 people, they fairly rapidly get into trouble. It's difficult to find examples of nations of more than 7 to 10 million people that don't have pretty severe, apparently insoluble, long-term problems. It just happened to come out that the natural scale of the space colony was small enough that simple methods of government — direct face-to-face hashing out of problems and so on — could work.



NASA ARTWORK BY DON DAVIS

**An artist's view of a more advanced space habitat, complete with forests, cities, and mirrors to control the sunlight.**

**Final Frontier:** Is this something we would want to test on Earth in an experimental community of 10,000 to 15,000 people before we put them in a sphere in space?

**O'Neill:** I certainly wouldn't object, but I would argue that there have been many societies on Earth of that scale that worked fine. There are human societies even at the present time that have surprisingly few barriers to the outside world, but which, because of strong motivating forces — usually religious — have kept themselves apart and have been, generally speaking, very successful sub-societies within a larger human society.

**Final Frontier:** It's the quasi-religious aspect that bothers some people.

**O'Neill:** I wouldn't want to draw the analogy to religion in that sense. The thing that appealed to me, and still does very strongly, is that people sharing a common goal and a common vision can go out to a specific colony and mold it to their liking and live there. If it turns out that some young people grow up in that society and don't like it, they can always move to another colony. That's a degree of freedom that we really don't easily have here on the surface of the Earth.

**Final Frontier:** Let's talk about the economics for a moment. $100 billion was the original estimate to build a colony for 6,000 people, including all the solar power satellites, lunar operations and so on, by the 1990s. Meanwhile, it's going to cost NASA $30 billion to build a small space station for eight people in that same time frame. Somebody's doing something wrong.

**O'Neill:** Well, I would have to say first of all that I would do the space station a totally different way if I were involved in that process. You shouldn't be doing something unless you have a real reason for it, and I am still groping to understand the reason for the space station as presently envisioned. It's not there for the military. The military, if it wants to put people into space, doesn't want to be part of an international consortium, and they probably want to be in different orbits.

Also, I think that anybody who still buys the idea that there's going to be substantial production in space of products that can only be made in zero gravity has got to be very deluded, because people have been trying to peddle that idea hard for a good ten years and there still are no examples. It's very hard for me even to imagine any successful examples of substantial industries that are going to develop *just* because of the zero gravity of space — industries which are going to sell to markets here on Earth. I'd be happy to be proved wrong, but the fact that so many intelligent people have been beating their heads against that wall for more than ten years makes me think that the whole idea of zero gravity manufacturing is a classic example of a technology looking for a reason.

which is the wrong way of going at technology.

**Final Frontier:** Still, it will take about ten years of high-level government expenditure to build a permanent space station for eight people. How, then, would it be only ten years from the decision to build space colonies to having 6,000 people living in space?

**O'Neill:** First let's ask the right question. We would not propose that you allocate an enormous block of money to build a space colony and that's it. In a sense that's as much of a dead end as the space station as it's often talked about. We — meaning we who have supported the work of the Space Studies Institute over the past ten years — see space colonies as the logical consequence of high-level industrial activity in space, which requires the presence of a number of well-educated workers, male and female. If you want to ask me when there is going to be a 10,000-person space colony, I would answer that it will be when the level of industrial activity in space is such that there have to be ten thousand adults out there working.

**Final Frontier:** Let's talk about what they are going to do out there. Is it still solar power satellites?

**O'Neill:** That still makes the most sense. It's been looked at by lots of different groups over the past years. When you look ahead to the energy needs of planet Earth over the next few decades and look at the alternative ways of producing that energy, solar power satellites look very, very good. It's the most environmentally non-polluting way of producing energy that you can do, and it is a totally renewable resource. I'd be scared as heck to think of energy in 2081 being provided by burning down the forests and burning up all the coal and polluting the atmosphere with carbon dioxide, or going nuclear on an enormous scale. It's not that I'm frightened of nuclear energy per se. It's just that as Chernobyl showed us, when you have a widespread nuclear power industry, there is bound to be a certain amount of sloppiness.

**Final Frontier:** Given the technical challenges of constructing solar power satellites, do you think some other solution to the energy problem might come along first?

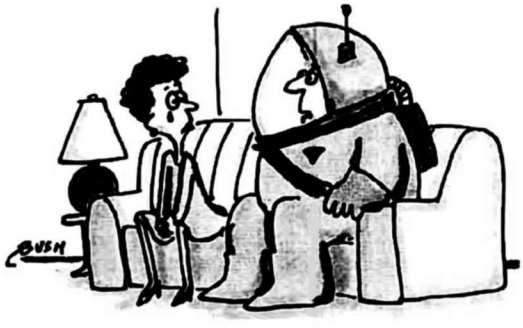
**O'Neill:** I'd say rather that it's the optimum long-term solution. It also requires the least technological development of any of the alternatives that are available to us other than just plain burning more coal and uranium.

**Final Frontier:** So the space colony idea is really driven by the need for energy?

**O'Neill:** In what you might call the awkward period, where the entire customer population is here on Earth, I think the answer is yes. I would compare it to the time when there were no significant colonies in the western hemisphere, but when useful trade items were being returned to Europe. During that period there was no reason for a large number of people to be settling in the new world.

If you go farther in the future to a time when a substantial fraction of the human population is living "off-Earth," then it's quite obvious that the colonies would be exchanging economically valuable commodities. The tricky period is the intermediate period when the consumers are on the Earth and the industrial production is in space. And the only example I see which is really large-scale and which can make a big difference to the economics and environment of the Earth is solar power from space.

**Final Frontier:** How many solar power satellites do you envision in orbit?




**No, there isn't anyone else. I just need some space.**

**O'Neill:** The scale that's been discussed is about ten gigawatts [billion watts] each. So, that's equivalent to the output of about ten big coal or nuclear power plants. The world needs for new energy are on the general scale of about forty such plants per year. If, for a viable industry, you're going to undersell competitive products, namely coal and nuclear plants, the cost is going to run on the order of a billion dollars per gigawatt. So one of these solar power satellites is worth about ten billion dollars on the hoof.

The question then is, what does it take to establish an industry in space which can build up to forty solar power satellites per year? The answer is that you don't lift that industry by brute force from the surface of the Earth. You go out to the surface of the Moon with relatively small scale mass drivers, chemical processing plants and small scale factories we call "job shops." You establish those on the Moon and in orbit, where they work, mainly under tele-operation from the Earth, to build more mass drivers, job shops and chemical process plants. In that way you replicate your industry and build it up to a level where you can start doing the end products like solar power satellites.

The way a realistic commercial enterprise has got to go — and I think of this still as a commercial enterprise and not a governmental enterprise — is that you've got to have milestones that will pay back within about five years. The first milestone is certainly not the $100 billion you mentioned before. The total investment that I would guess would be realistic and practical for the first stage is probably under a billion dollars. It's probably, at most, in the several hundred million dollar range.

**Final Frontier:** To do what?

**O'Neill:** The likely first generation products are very simple ones --- liquid oxygen for use in space transport and shielding material from the surface of the Moon to be used to allow long-term human occupancy of orbits above the Earth. Both of those are very expensive to carry from the surface of the Earth. They are relatively easy to get from the surface of the Moon. So you've got to design an industry that will do that for a total price tag of no more than a few hundred million dollars, or you haven't got a business. And you've got to get a payback in five years.

**Final Frontier:** Does that include people living on the surface

of the Moon?

**O'Neill:** I don't think it does. I think the first step is not one that involves people. I believe that in order to keep the prices down and to operate efficiently it ought to be a tele-operated system.

**Final Frontier:** So your answer to the question of whether a planetary surface is the best place for a technological civilization is still no?

**O'Neill:** Yes, I still believe very firmly in that answer. The important point is where does the human race want to be in 50 or 100 years? I think the very strong answer is that it wants to be largely off planet Earth, with all of the high growth of a technological civilization occurring off Earth.

**Final Frontier:** You were on the National Commission on Space, which looked ahead to our next fifty years in space. Yet there was no mention of space colonies.

**O'Neill:** They weren't taken as an end point. Another thing almost entirely excluded from the Commission's report was what is to me the primary economic rationale for the critical breakout into space, and that is solar power satellites. There were a lot of commissioners who were just fundamentally opposed to the idea. Some were strong believers in nuclear power who said it's totally unnecessary ever to have solar power from satellites. Others said the proper role of humanity in space is exploration and research, and there is no other role. There were even members of the Commission who said that if you went a hundred years into the future you would find no reason to be any farther out than low Earth orbit. That's what happens when you get fifteen people from various backgrounds around the table.

**Final Frontier:** Yet the Commission specifically looked at possible profit-making ventures in space.

**O'Neill:** Well, we did, but you have to remember the constraints we were under. The shuttle and the space station were virtually the only transportation systems or end-point habitats considered in the Commission's report. Space was looked at primarily as a field for exploration and research. But the one thing that came out clearly, even with that very tight and rather artificial set of constraints, was that it was very important to make use of non-terrestrial resources, to boot-strap our way out into the Solar System. That was a very strong conclusion, not because the commissioners said it, but because all of the experts that were brought in to talk about it said it, too.

So it didn't bother me that space colonies, per se, were not taken as an important end point. To me the critical successes of the Commission were such things as the initial ten points, which were coupled very tightly to the final title of the report, *Pioneering the Space Frontier*. Those are very emotion-laden words which very much carry the context of human settlement in space. So I was very happy with the results of the report. I think logic and reality will soon enough teach people who are working out in space that it makes more sense to be living in space colonies than on the surfaces of remote and hostile planets. I don't have to have that said in a presidential report. Plain common sense and economics is going to make that happen.

**Final Frontier:** If this is such an attractive commercial possibility, why are the energy companies not pursuing it?

**O'Neill:** For the reason that you cannot do it all in one gulp. We have to proceed by steps which are individually financeable and individually profit making and which can be done in five year steps. You need to go from small scale factories on the Moon to the point where you are producing 100,000 tons or so per year of finished products from materials in space. At that point you can start talking about making solar power satellites.

I don't think there will be any problem in interesting energy companies when you get to that point. The interest is potentially there. There was a write-up as long ago as the late '70s by the Edison Electric Institute, which took a hard look at solar power satellites. It's not something that the energy companies are going to be uninterested in when the right point comes. But they are not going to get from here to there in one jump.

**Final Frontier:** Last question. I understand you applied for the astronaut program at one time. Do you expect some day to visit a space colony named after you?

**O'Neill:** (Laughs) You can leave out the "named after me" part, but I would love to have a chance to travel in space. I hope that I will someday. Whether it happens or not is in the lap of the gods.

## Beyond Neptune

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just photograph the Solar System looking at the Sun," notes Kohlhase. "You have to carry out a special spacecraft maneuver in order to get a picture of, say, the Earth and perhaps a couple of planetary neighbors." The edge of Voyager 2's high gain antenna dish would have to be used to block the light of the Sun from the cameras. Too much blockage would also obstruct the camera's view of the planets themselves, and Voyager

**These will indeed be far encounters. The probe will not come within a light-year of any known star in the next 957,963 years.**

would end up taking a picture of nothing. But if too much light hits the narrow-angle camera, it could damage it.

The psychological effects of a photographic "view of the Solar System from interstellar space" could be immense. Photos of Earth taken by the Apollo astronauts had a powerful emotional and spiritual impact on millions. How profound might be the effects of seeing the entire Solar System in one image?

"Such a picture is definitely under consideration by the Voyager Project office," says Kohlhase. "They haven't yet decided yes or no. But if we do carry it out, we'll take the picture sometime between mid-October and the end of December 1989." And what happens to Voyager 2 after it dies? Its power gone, its hydrazine used up, its computers and instruments shut off forever, where will it head?

The answer has been worked out by Voyager navigator Bob Cesarone. Along with his colleagues Andrey Sergeyevsky and S.J. Kerridge, Cesarone has determined the "far encounters" Voyager 2 will have with other stars. "These numbers are not perfectly accurate," warns Cesarone. "But they're the latest ones we have."

In any case, these will indeed be far encounters. The probe will not come within a light-year of any known star in the next 957,963 years. It will pass about four light years from Barnard's Star in the year 10,559 A.D., 8,571 years from now. The spacecraft will next get within 3.2 light-years of Proxima Centauri in 20,319 years. A 4.3-light-year "driftby" of Sirius will follow 296,036 years from now. The spacecraft's closest stellar approach will happen 40,176 years after the Neptune encounter, when it comes within 1.7 light-years of the star Ross 248. Voyager 2 is indeed bound on a long, strange trip into the outer darkness.

Unless, of course, somebody someday goes out there and brings it back.

But that's another story altogether.

*Joel Davis is the author of Flyby: The Interplanetary Odyssey of Voyager 2. His book Mirror Matter, written with Dr. Robert Forward, will be published in June by John Wiley and Sons.*



## Mars

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embellished, or whatever. It should be asked to buy an objective of Mars."

However fervently each side argues its case, no solid decision has been made on where NASA is headed next. Whatever the decision, one sure bet in the nation's capital is that political timing is everything. Former NASA administrator Thomas Paine maintains that the next Shuttle countdown is an appropriate juncture to proclaim what the U.S. space program is really all about.

"I have strong feelings that the Moon versus Mars is a phony issue," says Paine. "The inner Solar System is our real destination. The Shuttle liftoff really means it is time that the U.S. set its course beyond Earth orbit, to the Moon and Mars. And it's time we started making it the public policy of the country."

As past chairman of the National Commission on Space, Dr. Paine is not hesitant to draw from the conclusions of the Commission's 1986 report, which outlined a whole program for pioneering the space frontier, including setting up a lunar base by 2005 and a Mars outpost a decade later.

For Paine, the real heart of the matter is not the Moon or Mars. Nor is it just fixing the Shuttle. "It is fixing Washington, D.C.," he claims. "The basic problem of NASA has nothing to do with the program, Shuttle O-rings, the Russians or foreigners trying to steal our secrets, lack of support of the American people, or space scientists not being able to have careers. It is a very simple thing. NASA is no longer effectively communicating with Washington, D.C."

When space shuttle Discovery climbs into the Florida sky this year, it will reconnect the public to NASA's space program and the promises of adventure yet to come. That liftoff constitutes a shakedown of national will and purpose, as well as technology.

Can the United States afford to set sail on a new course in space? Can it afford not to? Choosing a challenging goal will require far more than just words. In the final analysis, the decision will mirror how America sees itself and its place in history.

After all, what's a future for?

*Leonard David is Director of Space Data Resources and Information, a Washington, D.C. consulting group, and a former director of research for the National Commission on Space.*

## Look Back

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understanding of the experience much better than when he was interviewed for the Omni article. He explained that his breakthroughs came from being completely open to the initial experience and then spending sixteen years interpreting it. Today, he is close to developing a systematic structure for describing his experience with great precision. In terms of its eventual implications, Mitchell says that he sees spaceflight revolutionizing our value systems:

> Spaceflight is one of the more powerful experiences that humans can have, and the technological event of breaking the bonds of Earth is far more important than the technology that went into it, because of this perspective...
> Spaceflight, getting outside of Earth and seeing it from a different perspective, having this sort of explosive awareness that some of us had, this abiding concern and passion for the well-being of Earth ... will have a direct impact on philosophy and value systems. It's got to be investigated far more thoroughly.

Schweickart's experience was the foundation for the Association of Space Explorers, and Edgar Mitchell founded the Institute of Noetic Sciences and is constructing an entirely new philosophical system based on his experience. In this way, the impact of space on a single astronaut is amplified throughout society and may affect the lives of millions.

Something significant happened to the astronauts who went to the Moon and to the nation that sent them there. To some extent, neither the astronauts nor the nation has been quite the same since. The lunar missions were a transformational reaching outward by humanity, followed by a long period of equilibrium, which continues today. These missions were shaped by the politics of Earth at the time and produced unpredictable results that will profoundly affect the politics of the future.

*From the book THE OVERVIEW EFFECT: Space Exploration and Human Evolution by Frank White, published by Houghton Mifflin Company, Boston. Copyright ©1987 by Frank White. Reprinted by permission.*

# BOUNDARIES

## Beam Me Up, Arthur

*Laser light and ice could be the transport of the future.*

▼ ▼ ▼ ▼ ▼

*By T.A. Heppenheimer*

In days of old, when rocketeers were bold and lasers weren't yet invented — during the early 1950s, that is — the town of Oro Grande, New Mexico was the railhead where U.S. Navy researchers would offload experimental Viking rockets to be fired from the nearby White Sands Missile Range. Today, near Oro Grande, the U.S. Army's Strategic Defense Command is building a site for the world's largest laser. When it's finished in 1991, one of its most revolutionary uses may be in developing an entirely new rocket principle: laser propulsion.

Arthur Kantrowitz, Dartmouth professor and longtime leader in both rocketry and lasers, invented the concept in 1972. Kantrowitz avoids the decades-long debate between advocates of liquid-fuel rockets, which offer high performance but require complex pumps and plumbing, and solid fuel advocates, whose rockets give less performance but need only a strong casing and a nozzle. His rocket eliminates all pumps, casings, and dangerous or explosive fuels. It even eliminates the nozzle. In fact, Kantrowitz says, "Let's leave everything on the ground except payload, propellant, and photons — period."

This "four-P" principle amounts to a space-bound payload resting on a block of hydrogen-rich material, plus a laser beam, and that's all. Laser pulses aimed at the block would blast thin layers of material from its surface, which would expand to produce thrust. The range of possible hydrogen propellants (hydrogen gives the greatest exhaust velocity) is astonishingly wide. Ice — ordinary frozen water — is one possibility. Blocks of plastic also would do. These polymers might approach the chemical makeup of common coal, which also contains a considerable amount of hydrogen, raising the intriguing possibility of a coal-fired rocket.

Dennis Reilly of the Avco-Textron research laboratory, a longtime Kantrowitz associate, has proposed the use of closely spaced double pulses of energy for the rocket's laser beam. The first pulse, relatively weak, would blast away a small amount of material, which would form a film of evaporated gas over the bottom face of the block. The second pulse, much stronger than the first, would then deliver energy to this film and make it expand rapidly. This technique could allow the exhaust to reach temperatures — and therefore velocities — far higher than those of conventional rocket fuels.

The Pentagon's Strategic Defense Initiative office is pursuing a modest research effort, funded at around $2 million per year, to develop the technology of laser propulsion. During the next two years, the SDI research will focus on understanding the basic physics of laser-propellant interactions well enough to permit the engineering design of test rockets for use with existing lasers. This is to be followed by static, or ground-based, laser rocket tests in 1990.

The rocket firings could be carried out as extensions of large-laser experiments currently under way at Lawrence Livermore National Laboratory in California, which use the Advanced Test Accelerator as an energy source. Livermore's accelerator produces electron beams with 50 million volts of energy, fired in brief pulses. This energy, converted to laser light, would be directed at test rockets in the early experiments.

In addition to such static tests, considerable effort will be devoted to learning how to control and maintain stability of a laser-powered rocket in flight. One proposed method for tilting the rocket's path is simply to move the laser beam off-center.

If these tests look promising, the SDI propulsion program is expected to develop flyable laser rockets during 1991 and 1992, beginning with tethered test vehicles for flight within a laboratory, and progressing toward actual launches using the Ground Based Free Electron Laser, the big system now a building near Oro Grande.

This laser is powerful enough that it actually "has the prospect of lifting something," notes Jordin Kare of Livermore, the laser-propulsion program manager. "I think of it as delivering a grapefruit to the space station (at an altitude of 250 miles)."

The launching of even a grapefruit-sized satellite would lay the groundwork for proposals to build an even larger laser. Present studies show that a laser rocket could deliver some 15 percent of its total liftoff weight to orbit as cargo. By contrast, only 1.5 percent of the space shuttle's liftoff weight is payload.

The cost of the electricity used by a laser for such a launch is estimated at about $18 for each kilogram (2.2 pounds) placed in orbit, compared to a cost of about $10,000 per kilogram for shuttle-launched payloads. If it ran continually, a laser launcher could lift 64,000 tons of payload per year to low orbit.

Once they've arrived in space, many payloads still need a further boost to reach geosynchronous orbits 22,000 miles above the Earth. So William C. Brown, of Northwestern University, has proposed a possible next step.

He would use a radio frequency transmitter to beam microwaves to an orbiting spacecraft, which would receive them using an antenna. The microwaves would carry enough energy to power a low-thrust electric rocket onboard the spacecraft. This high-performance engine would drive the spacecraft in a very slow spiral up to higher orbits, relying entirely on microwaves beamed from the ground for its energy.

With lasers for the initial boost and microwaves for the climb to higher altitudes, the call, "Beam me up, Scotty," could take on new meaning in the next century. □

# DESTINATIONS

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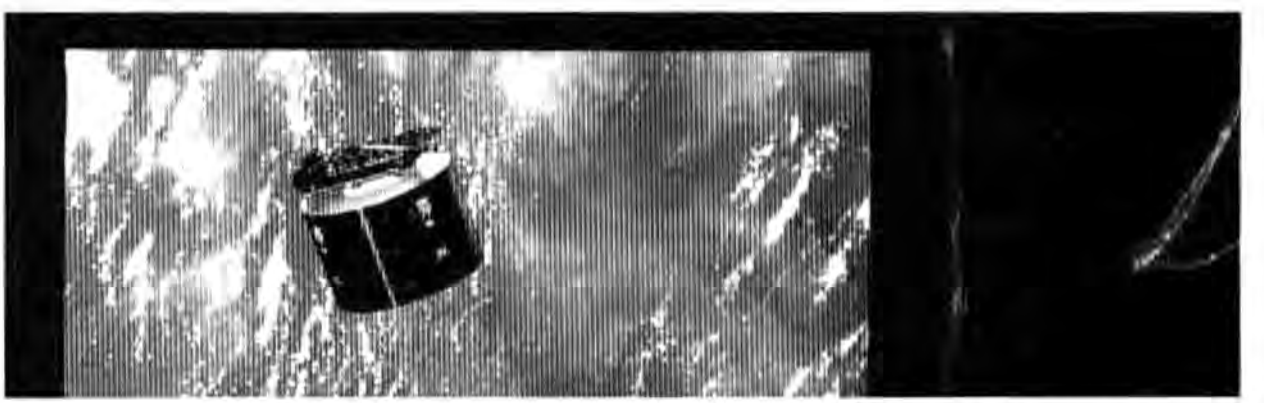

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